Metal Progress

JUNE 1959

Another new application for **TITANIUM**

PUMPING HIGHLY CORROSIVE SOLUTIONS?

Titanium provides the answer in "Durcopumps"®

The Duriron Co., Inc., designers and manufacturers of equipment for corrosive service, is among the first to take advantage of titanium's outstanding corrosion resistance in pumps and pump parts.

Working closely with Duriron engineers, Mallory-Sharon helped develop welding and forming techniques for production of a fabricated titanium centrifugal pump. Durcopumps, *with all wet end parts fabricated of Mallory-Sharon commercially pure titanium,* are being produced to order, for pumping hot nitric acids, hot chlorides, etc.

As proof of titanium's superior corrosion resistance, operation of a million-dollar chemical plant was being held up for lack of a suitable pump to handle boiling 65% nitric acid. Cost of downtime was $1,000 per day. Two titanium centrifugal pumps were installed in the line. To date, they have given *over 12 months' service*—compared to less than 30 days' service for nickel-base alloys previously used.

Mallory-Sharon engineers are ready to work with *you* in applying titanium. Write for Technical Data Sheet on *"Titanium Pumps for Chemical Service"*. Please address: Commercial Market Development, Dept. B, Mallory-Sharon Metals Corporation, Niles, Ohio.

MALLORY MS SHARON

MALLORY-SHARON METALS CORPORATION · NILES, OHIO

Integrated producer of Titanium · Zirconium · Special Metals

Metal Progress

June 1959 . . . Volume 75, No. 6

Cover shows a rare earth refining furnace in action; details of the operation are given on p. 112. The photograph was taken almost entirely by the light emitted by the furnace.

Progress in Finishing

Engineering Articles

Table of Contents Continued on Page 3; Volume Index on Page 237.

**The coding symbols refer to the ASM-SLA Metallurgical Literature Classification, International (Second) Edition, 1958*

Centrifugally cast Thermalloy tube burst at 77,500 psi

Wrought tube burst at 70,100 psi

Burst tests prove 7,400 psi superiority of centrifugally cast Thermalloy® tubes

Hydrostatic pressure tests by Electro-Alloys established the rupture of a centrifugally cast Thermalloy tube section at 77,500 psi. Under the same conditions, wrought tubes of comparable section and analysis burst at 70,100 psi. These tests were conducted at room temperatures. Tensile tests show this strength margin increases substantially at the higher operating temperatures (1200°-2200° F). The Thermalloy tube was tested *as cast* —without machining the inside or outside diameter.

Thermalloy is a group of heat-resistant alloys developed for use in the range of 1200°-2200° F. The greater strength of the Thermalloy centrifugally cast tubes makes them ideal for use in radiant tubes, retorts, rolls or other heat-resistant designs employing tubes. For further data, call your representative, **or** write Electro-Alloys Division, 1016 Taylor St., Elyria, Ohio.

AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION • Elyria, Ohio

Metal Progress

Contents Continued

Metal Progress is published monthly by the American Society for Metals. Publication office Mt. Morris, Ill. Editorial and general offices 7301 Euclid Ave., Cleveland 3, Ohio. Entered as second class matter at the Post Office in Mt. Morris, Ill. Vol. 75, No. 6, June 1959.

Press Breaks...

Last month the Editor-in-Chief reported some observations resulting from his trip to the Western Metal Congress in mid-March. Also representing *Metal Progress* at the Western Show were Editor Gray and Assistant Editor Weymueller, both of whom had some interesting side trips and experiences.

Editor Gray spent a busy ten days prior to the Western Metal Congress visiting with experts in aircraft and missile companies in the San Diego and Los Angeles area. On the day he visited North American Aviation he found some of the N.A.A. people in a frenzy because the famed X-15 space ship was being taken aloft for the first time. But this was no ordinary flight because the X-15 was hung under the wing of a B-52 and taken up some 40,000 ft., then brought back down again. It was a dry run so the pilot, Scott Crossfield, could get the feel of some of the many mechanical and electronic gadgets which will control the ship. When the day comes to set the X-15 free of the mother ship, it will turn its nose upward and rise some 100 miles, then glide downward in a steep dive reaching a speed of 3600 miles per hr.

This test took place at Edwards Air Force Base out in the desert but N.A.A. had two more X-15s in the plant and Al Gray had a chance to look them over to his heart's content. Perhaps you saw the X-15 on TV that day and if you thought it looked more like a missile than an airplane, Al says you were right. It's really something to build an airplane to stand air friction heating at 1 mile per sec. N.A.A. engineers decided on a thin Inconel skin and the welding experts had their troubles putting it together.

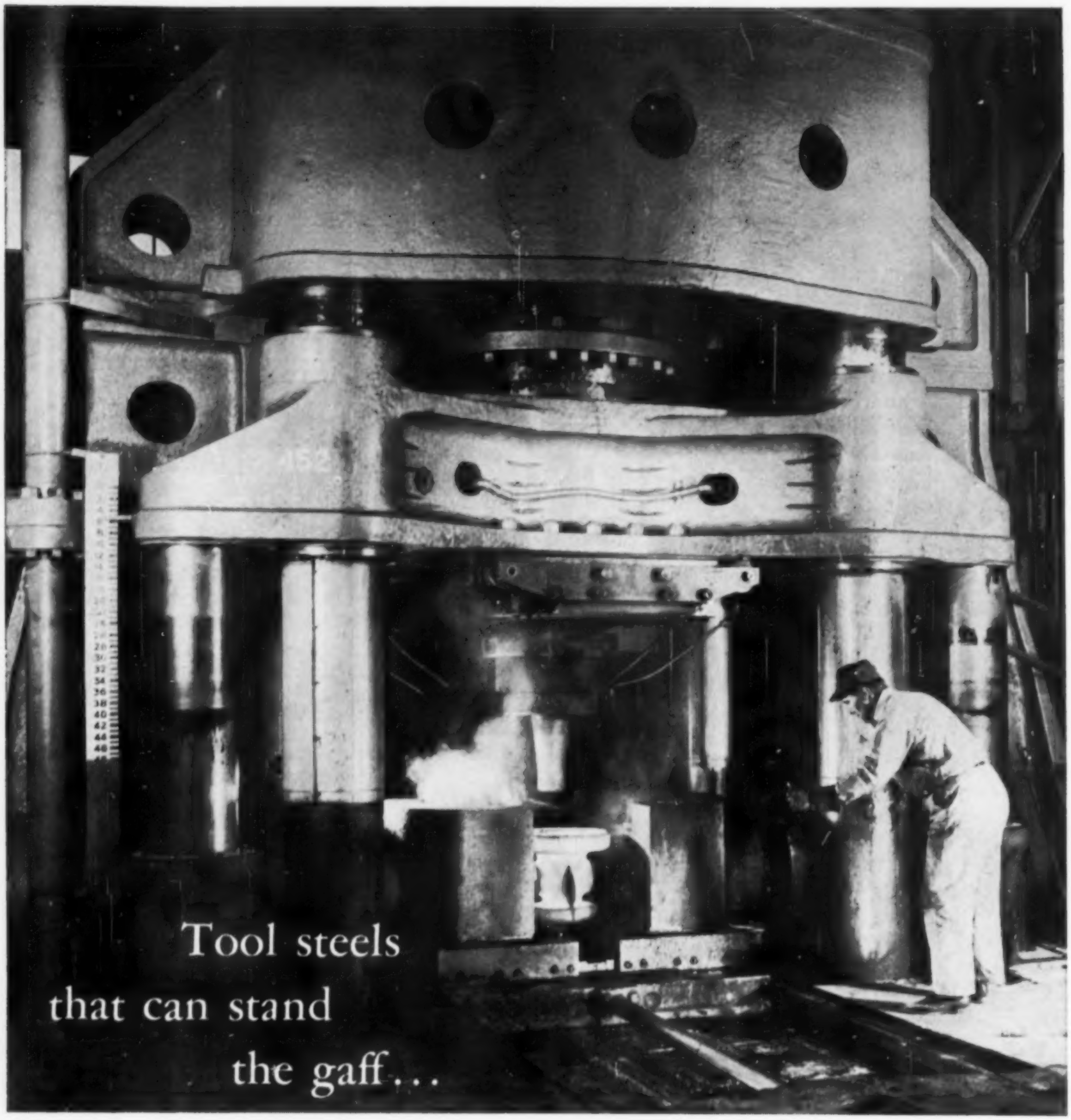
North American was busy making pictures of the X-15 that day which suited Al too. They presented him with a large photo of the space ship to use the next day when he spoke on space metals at a luncheon of the Los Angeles Kiwanis Club.

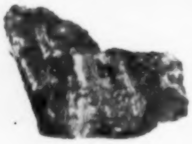
The third member of our traveling group, Carl Weymueller, apparently regarded the trip as a vacation since he used a weekend to visit Disneyland – to inspect their metallurgical problems, he claimed. He reports that they have much less trouble with their moon rocket that do the Cape Canaveral engineers. It takes off (from Los Angeles airport, of course), circles the moon, and returns –all with scarcely a quiver. You don't even need seat belts, and this is all the more remarkable in view of the incredible speed. The round trip (over 500,000 miles) takes only 10 minutes!

Metallurgists immersed in construction problems will be interested to know what goes inside a mountain. Disneyland builders – now erecting the Matterhorn – are about halfway finished. The interior is not yet covered; it looks like a pile of jackstraws, but is actually composed of I-beams supplied by American Bridge. According to erectors, the Matterhorn will be ready for bobsled rides by this summer. This just shows how Man can improve on Nature; the original Matterhorn took eons to build.

When gently reminded that he had been expected to do a little work, Carl also reported that he managed to cover the A.S.M.E. and S.N.T. meetings as well as visit the Northrop and Hughes aircraft plants between sightseeing tours. So maybe we'll send him again; we haven't decided yet.

The Editors


Tool steels
that can stand
the gaff . . .



Metal Progress

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Publishes *Metals Handbook*, an encyclopedia of metals; *Metals Review*, news magazine; *Review of Metal Literature*, abstracting service; *Transactions*, scientific annual; Career technical books on metals.

Educational activities: Operates National, Western, and Southwestern Metal Congresses and Expositions; prepares and administers courses for Metals Engineering Institute for home, in-plant or American Society for Metals Chapter study.

Fast moving Macomber..

An example of progress, Robert Macomber, president, displays one of Macomber's fine products—V-Lok structural framing that goes together without bolts, rivets, or welds.

PHOTO BY KARSH OF OTTAWA

Quality steel is vital according to James E. Stiles, vice president of production at Macomber.

.bases growth on advanced engineering–

Quality Steels

Reliable steel service is necessary in the fast moving construction business says Norman C. McGregor, purchasing agent, shown here with Sharon salesman Lynn Houston.

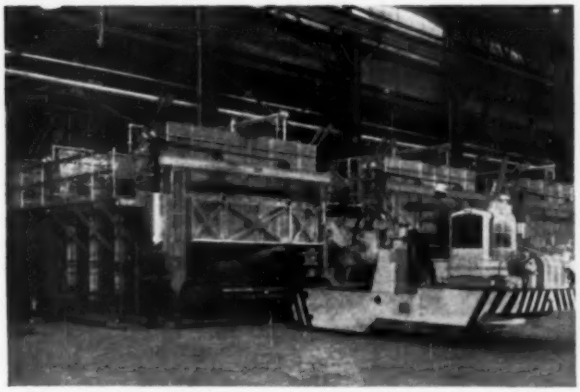
Since the war the construction industry has experienced phenomenal growth. Even so, few concerns associated with the construction business were able to record progress at the pace set by Macomber Incorporated, Canton, Ohio, manufacturer of steel joists, roof decking, and structural steel framing.

"Advanced engineering—quality product", Macomber executives agree were the main reasons for their steady drive to national prominence. "Our engineering is second to none", says Robert Macomber, president, "and we're extremely quality conscious. In this area we know we have to rely on quality minded suppliers. We like the steel from *Sharon Steel Corporation, Sharon, Pa.*"

The best designs result from a good knowledge of materials and faith in the supplier to deliver, says J. W. Hubler, vice president of engineering.

SHARON *Quality* **STEEL**

SHARONSTEEL

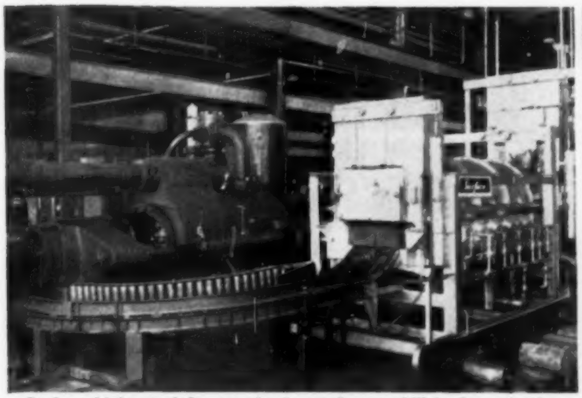


A big aluminum billet is removed from one of a battery of Surface furnaces which heat 7000 lbs/hr each for forging.

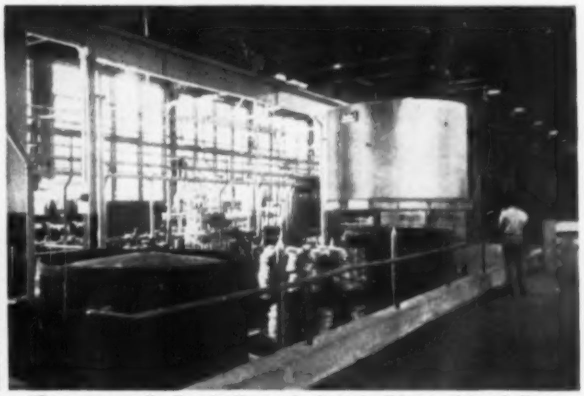
Thousands of 14S aluminum parts a day are solution heat treated and aged in this Surface continuous furnace line.

with new method by Surface

wherever heat is used in industry

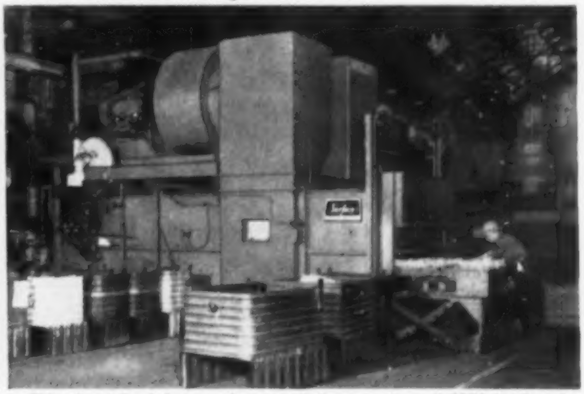


Surface high-speed furnace heats nonferrous billets for extrusion at a rate of 19,250 lbs/hr, with fine grain size.



"Super convection" cuts the cycle time in this precision bell annealer. Direct-fired heating's in the base.

Specified grain size of 0.040 mm is held easily in this Surface continuous bright annealer for copper tubing.



This direct-fired furnace has a rated production of 2500 lbs/hr of aluminum blocked forgings.

REPUBLIC ELECTRUNITE

world's widest range of

SPECIALTY WELDED TUBING

STAINLESS and CARBON

STAINLESS

HEAT EXCHANGER, CONDENSER AND EVAPORATOR — Full Range of Sizes and Analyses

PIPING — Complete Range of Sizes in Schedules 40S, 10S and 5S

AIRCRAFT—Exhaust Stacks, Hydraulic Lines and Duct Tubing

SPECIAL BRIGHT ANNEALED — Up to 4" O.D. — Special Shiny Surface

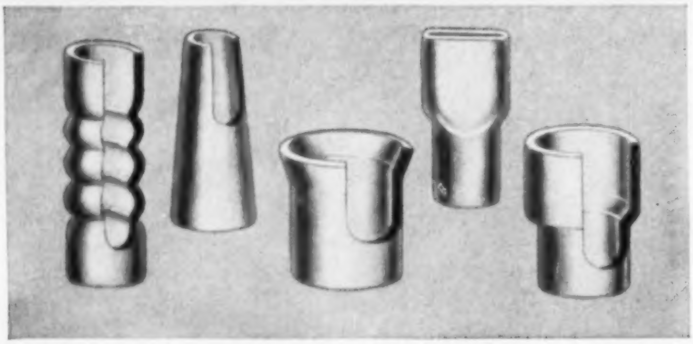
CARBON

HOT ROLLED — 1/4" O.D. thru 6" O.D. — 16 Gage thru .250"

COLD ROLLED — 3/8" O.D. thru 6" O.D. — 22 Gage to 10 Gage

AIR PRE-HEATER — Full Range of Sizes

SPECIAL SMOOTH I.D. HYDRAULIC CYLINDER — Up to 4½" I.D. and in Wall Thicknesses up to .187"



REPUBLIC ELECTRUNITE MECHANICAL TUBING is easily fabricated and formed by the user or through the fabricating and finishing facilities of Republic's Steel and Tubes Division. Round tubing can be furnished flanged, swaged, flattened, fluted, spun, configured, upset, rolled, and otherwise changed in cross-section to meet an endless variety of design requirements. Write for illustrated brochure.

Republic ELECTRUNITE® offers you the world's widest range of stainless and carbon tubing. Carbon steel round tubing in sizes up to 6" O. D.—squares and rectangles in peripheries up to 20". Stainless steel tubing in sizes up to 5" O. D.—squares and rectangles in peripheries up to 16". And a complete range of stainless pipe sizes.

ELECTRUNITE is quality controlled from ore to finished product. Produced in Republic's own mills to rigid requirements.

Welded by the exclusive ELECTRUNITE process—a continuous electric-weld method that unites the wall under pressure without the addition of foreign or extra metal. Tests prove the weld is as strong or stronger than the original base metal.

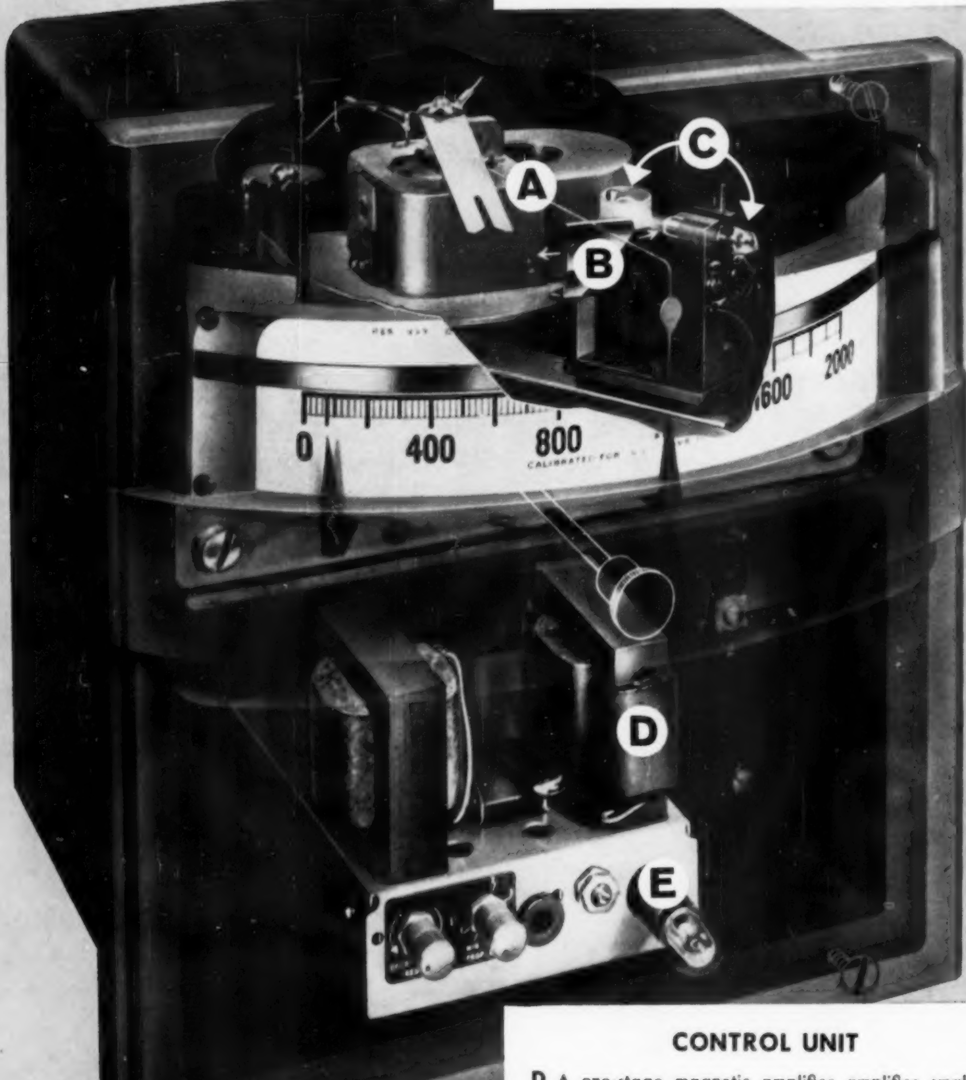
Next time you need tubing, whatever the application or problem, call your Republic representative. Or, write direct.

MEASURING UNIT

A. A thermocouple signal to a d'Arsonval galvanometer, the only moving part, moves the indicating pointer up scale.

B. Aluminum vane adjusts the amount of light received by the photocell from the operating lamp.

C. If operating lamp or photocell fails, output voltage assumes a value equal to high temperature.

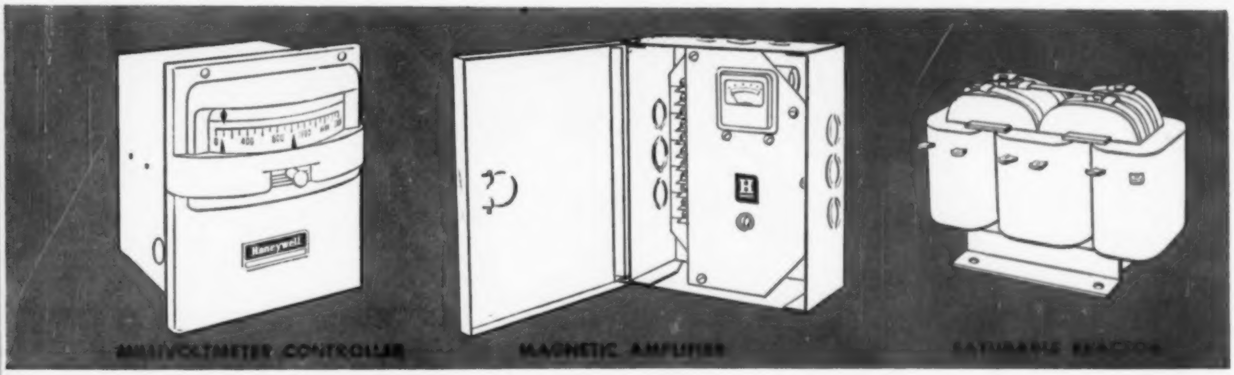


CONTROL UNIT

D. A one-stage magnetic amplifier amplifies small current from the photocell in the measuring unit. This is the only active electronic element in the controller.

E. Pilot light goes out on line power failure.

***Pyr-O-Volt* controller is dependable and trouble-free. Built-in voltage regulator maintains voltage within ± 1% of level required for maximum operating stability. Thermocouple burnout protection is optional. Spare operating lamp is supplied with all instruments. Available in both horizontal and vertical case models.**



For your electric heating applications . . .

Use this accurate, dependable *Pyr-O-Volt** controller

- **No tubes to wear out**
- **Voltage regulation**
- **Fail-safe design**
- **Contactless, stepless control**

Here's an accurate instrument for reliable stepless control of saturable reactors, r.f. generators and other power amplifiers. It has a proportional band adjustable from ⅔% to 5%, and a manual reset adjustment which shifts the control point over 100% of the proportional band.

The *Pyr-O-Volt* controller can control saturable core reactors up to 100 kva, if used with a Brown magnetic amplifier. You can also use this proportional output millivoltmeter-controller with the General Electric *Reactrol***, and with the Westinghouse *Furnatron*.*** Complete packaged systems available.

Contact your nearby Honeywell field engineer for complete details. He's as near as your phone.

MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.

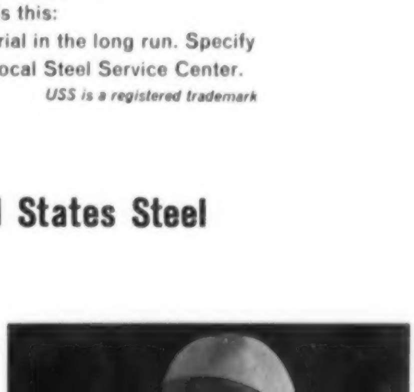
Honeywell

H HONEYWELL *First in Control*

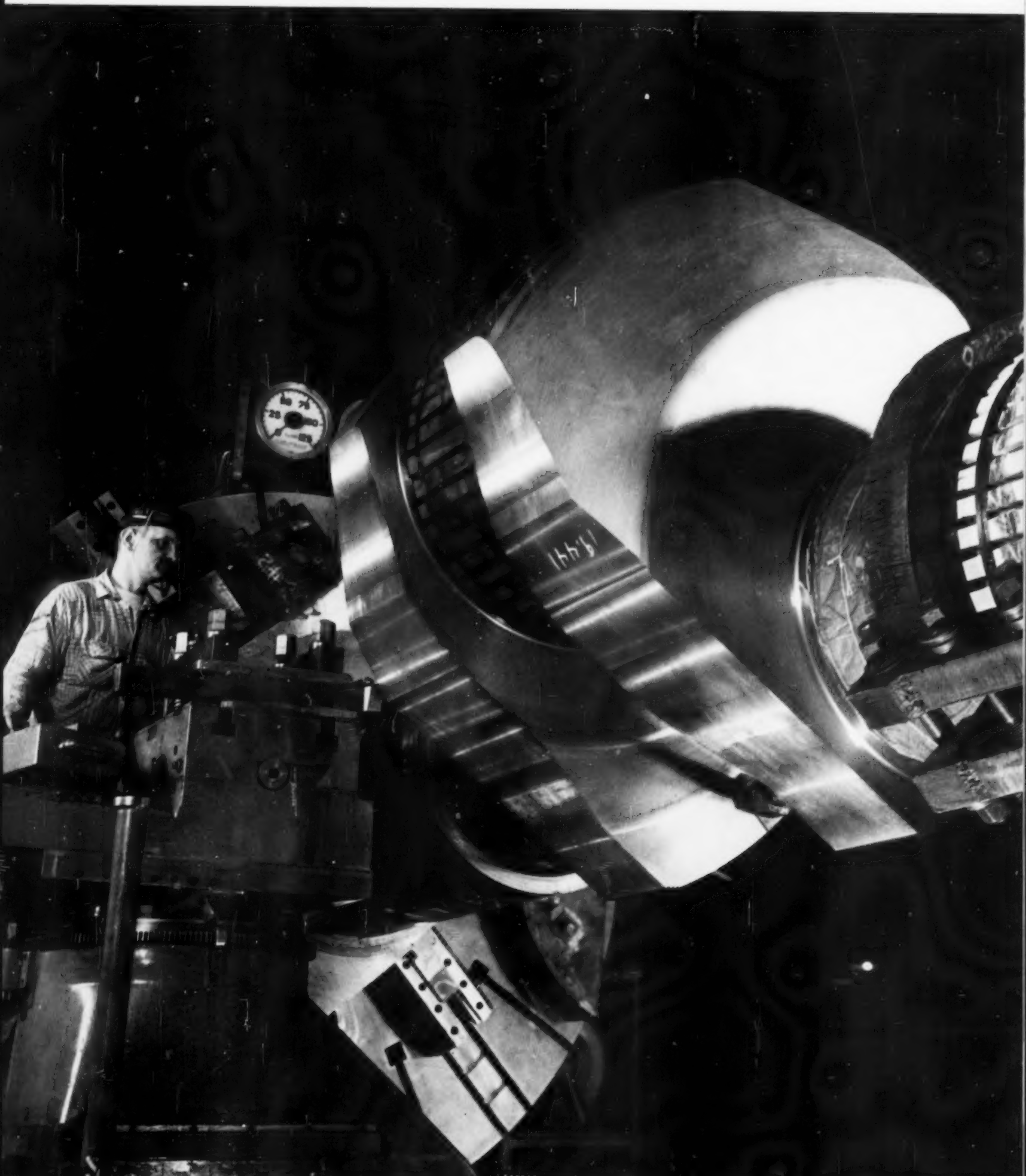
● **REFERENCE DATA: Specification S103-5**

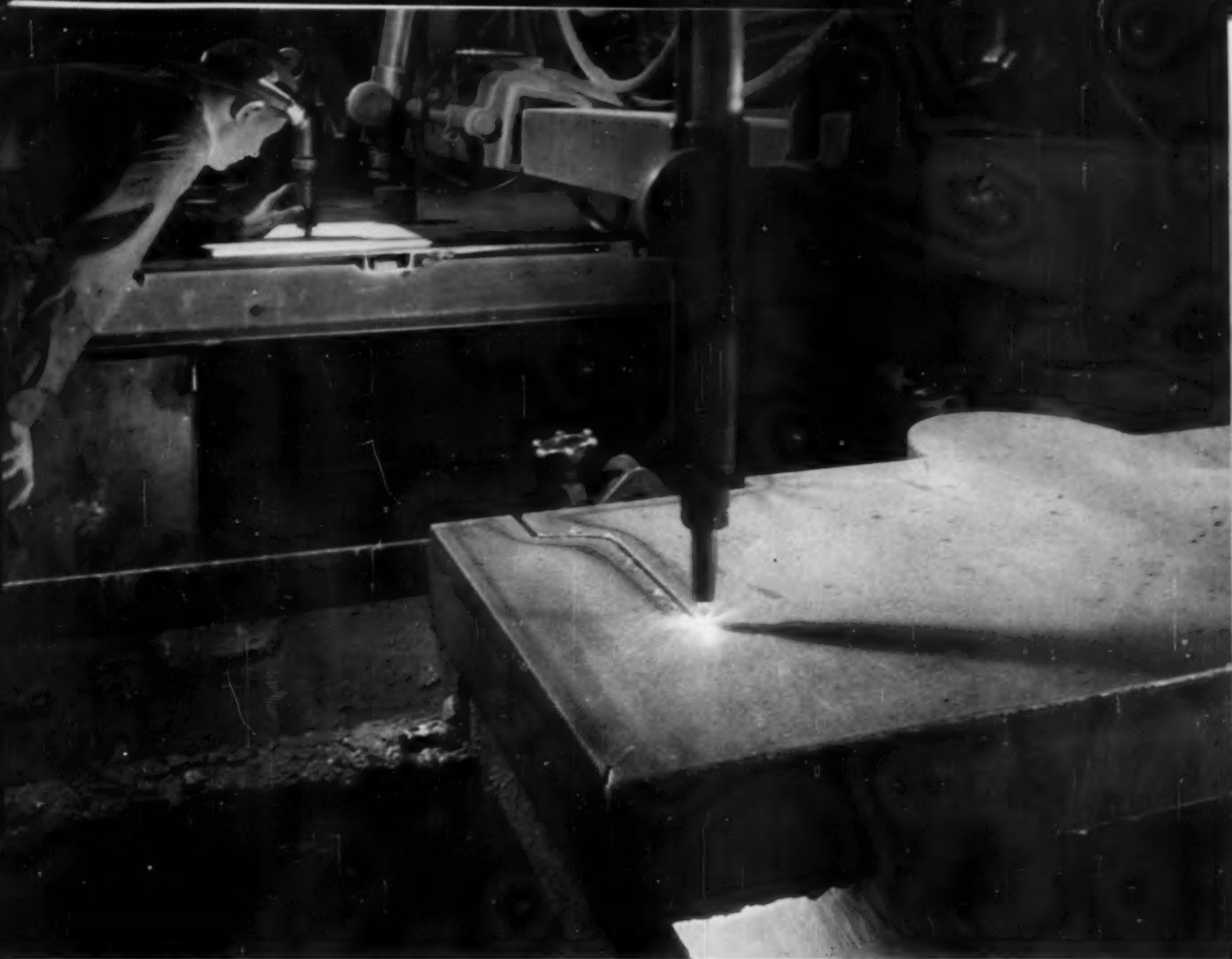
*Tradename, Minneapolis-Honeywell Regulator Co.
**Tradename, General Electric Co.
***Tradename, Westinghouse Electric Corp.

Here is one of a fleet of forty Type 430 Stainless Steel tank cars that transport nitric acid. Built in 1956 by General American Transportation Corporation, these tank cars are still in excellent condition.



"60 tons of counterweights de-shimmied this shaft"





4400° F in Three Minutes

NEW HIGH TEMPERATURE VACUUM FURNACE

- ***Large 6" I.D. x 10" Heating Element***
- ***Automatic Protective Devices***
- ***Operates at 10^{-5} mm Hg or with Inert Gas***

Connect water, power, air and drains to the NRC Model 2915 and you're in business. That's just the first convenience you'll experience when you use this new refractory-free resistance furnace to sinter or heat treat reactive or high temperature metals and ceramics!

Loading, unloading, and cleaning are quick and easy. With one finger you can raise the spring-loaded stainless steel cover and lift out the top heat shield assembly. For cleaning, the heating element and other shield assemblies can be removed in less than 30 minutes. Every square inch of the stainless furnace chamber is accessible. Graphic control panel simplifies operation.

The three-phase cylindrical heating element offers long, trouble-free life because of its rugged construction, three point support, and ample spacing from heat shields.

This furnace will help you make more money. Large capacity, rapid heating and cooling, and high speed evacuation increase productivity. Double glass sight port, interlocked, fail-safe pumping system and power supply protect work and heating element against excess pressure and temperature. Special circuit prevents air-releasing before work is sufficiently cool.

Send for more information today!

NRC
EQUIPMENT CORPORATION

SALES OFFICES: Atlanta • Boston • Chicago • Cleveland
Detroit • Houston • Los Angeles • New York • Palo Alto • Pittsburgh

NRC EQUIPMENT CORPORATION
A Subsidiary of National Research Corporation
Department 1F, 160 Charlemont Street, Newton 61, Massachusetts

☐ *Please rush me data sheet on NRC Model 2915 Vacuum Resistance Furnace.*
☐ *Please have sales engineer call.*

NAME...TITLE..................

COMPANY..

STREET...

CITY, ZONE, and STATE..

APPLICATION and EQUIPMENT new products

Vacuum Furnace

A high-vacuum resistance furnace with hot zone capacity to handle production or laboratory work at temperatures to 4400° F. has been announced by NRC Equipment Corp. Furnace chamber, pumping system, power supply, and controls are in one cabinet. Model 2915 can be operated at absolute pressures of 10^{-5} mm. Hg

or under inert atmospheres. Vacuum is achieved by a 30-cfm. rotary gas-ballast pump for roughing operation and a 6-in. oil-diffusion pump for evacuation in the high-vacuum ranges. The furnace has a heating unit approximately 6 in. in diameter and 10 in. high that reaches heat in about 6 min. and cools in 20 min.

For further information circle No. 1179 on literature request card, page 48-D.

Gold Finish

Allied Research Products, Inc., has announced a new gold dye for use over a clear Iridite film. The new process is applicable to such zinc-plated products as refrigerator shelves, wire goods and tubing. It is applied to the clear chromate conversion coating by a 15 to 30 sec. immersion in the dye solution which operates at between 70 to 90° F.

For further information circle No. 1180 on literature request card, page 48-D.

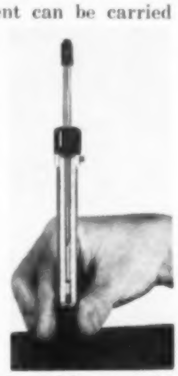
Stainless Alloys

A new group of molydenum-containing alloys of the 18-8 type and designated as the PH55 series has been announced by Cooper Alloy Corp. In the high-temperature field (1000 to 1400° F.) these new alloys offer higher strengths than can be obtained with existing precipitation hardening alloys of the corrosion-resistant type. Alloy PH55A has high strength, high hardness and pitting resistance. Alloy PH55B has high strength, greater ductility and lower hardness, making it suitable in applications where corrosion resistant parts are subject to stress and shock. Alloy PH55C has greater corrosion resistance, hardness and strength than PH55A but is less ductile and shock resistant.

For further information circle No. 1181 on literature request card, page 48-D.

Hardness Tester

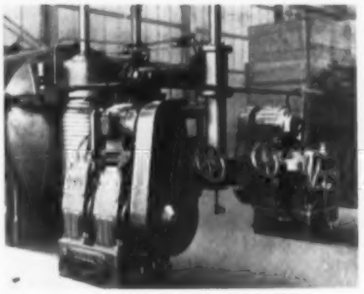
A new portable hardness tester has been announced by Precise Products Corp. The instrument can be carried in a shirt pocket and enables the user to make on-the-spot hardness readings. Operating on the rebound principle, the Sklero hardness tester provides readings to within plus or minus one point on the Rockwell C scale. The instrument is placed in a vertical position on the article to be tested. The rebounding bar which carries a hardened steel ball point is raised, and when released, it rebounds to a point corresponding to the hardness of the object and is locked into position for reading.



For further information circle No. 1182 on literature request card, page 48-D.

Metallizing

A new 72-in. vacuum coater with fast pump-down to the metallizing pressure has been announced by the Vacuum Equipment Div. of F. J. Stokes Corp. The pumping system reflects a new modular approach to vacuum system design. It is composed of two identical teams of mechanical pump, diffusion pump and booster



pump, each team connected independently to the vacuum chamber through its high-conductance manifold and high-vacuum valve. The coater is normally operated with both pumping teams, but it can be operated successfully with a single team or with any combination of mechanical pumps and diffusion - plus - booster - pump pairs. Pumping down the clean dry chamber to the normal coating pressure can be accomplished in 5 min. The figure above shows the pumping system of the metallizer.

For further information circle No. 1183 on literature request card, page 48-D.

Tempering Furnace

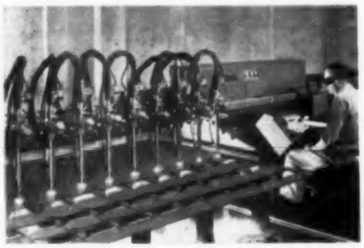
A new general-purpose furnace designed for tempering and drawing jobs requiring close temperature control has been announced by C. I. Hayes, Inc. Maximum temperature is 1250° F. and a uniformity of ±5° F. is maintained during the treatment cycle. The furnace comes with proportional heat control that provides maximum power during heat-up, and minimum power requirements when set temperature is reached. Chromel-A

elements work with fan-induced circulation of air to accelerate heating and insure even distribution. Work baskets measure from 22 to 36 in. in diameter, and from 30 to 48 in. in depth. A gear-type mechanism permits opening and closing of the heavily insulated lid.

For further information circle No. 1184 on literature request card, page 48-D.

Cutting Machine

A new automatic shape-cutting machine has been announced by Linde Co. The Oxweld CM-60 is powered by two electrically coordinated motors providing power for every type of flame-cutting operation. Standard models can be equipped with 10



torches to cut any width up to 10 ft. The thickness of metal that can be cut is limited only by the capacity of the torches used. The Oxweld CM-60 is equipped with a photoelectric tracing system that automatically compensates for kerf width. Pencil and ink sketches on paper guide the tracer.

For further information circle No. 1185 on literature request card, page 48-D.

Cleaning System

Ultrasonic cleaning systems in matched counter-height cabinets have been announced by Branson Ultrasonic Corp. The series C cabinets, welded of 16-gage type 316L stainless steel

to uniform dimensions (26 by 24 by 32 in.) house the generator, the cleaning tank, filter, rinse tank, and dryer. Different combinations and arrangements are possible, depending on needs of the user. A standard installation consists of three basic units: generator, tank and filter. To these, rinse tank and dryer may be added. Radio-frequency output of the ultrasonic generator at 40 kc. is 500 w. average, 2000 w. peak on pulses. Power input is 1.5 kw., 115 v., a.c. (50 to 60 cycles), or 220 v., single-phase a.c. Generator is forced air cooled.

For further information circle No. 1186 on literature request card, page 48-D.

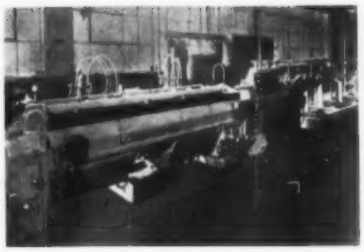
Furnace Controls

A new electronic device for maintaining uniform time and temperature in heat treating furnaces has been announced by the A. F. Holden Co. An electronic timer can be preset for both time and temperature through two phases of the heat treating process. Once the preset time and temperature controls have been fixed and the furnace started, they cannot be changed. Advantages claimed are reduction in fuel costs, uniformity of heat penetration and minimizing of distortion.

For further information circle No. 1187 on literature request card, page 48-D.

Bar Processing

An automatic machine for the continuous cold drawing, straightening, cutting and polishing of bars from coiled rod has been announced by Loma Machine Co. It is capable of turning out cold finished rounds, squares, hexagons and rectangular sections in sizes from 3/16 to ⅝ in.



at a speed of 200 fpm. In the production of ⅝-in. rounds, this speed results in an output of 5 tons per hour, based on 20% downtime for coil feeding and tooling changes. The line consists of an uncoiler, a pre-straightener, a drawbench, a roller straightener, a flying cutoff, a polishing machine and a discharge table. The picture above shows the continuous drawbench and roller straightener.

For further information circle No. 1188 on literature request card, page 48-D.

Sintered Carbide

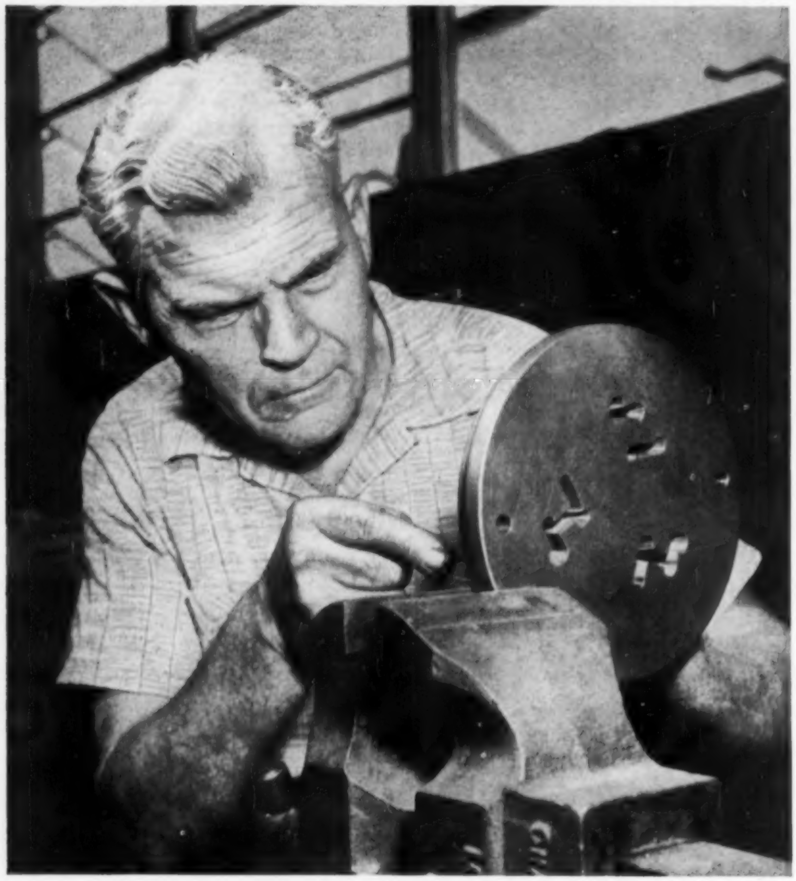
Kennametal, Inc., has announced that its K11 carbide with a hardness of Rockwell A 93 is now available as button inserts. It was previously produced as throwaway inserts. This carbide will turn 1213 steel rotors at 398 sfm. (2550 rpm.) and machine from 7500 to 9000 pieces per insert. In ma-

Tool Steel Topics

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

Export Distributor: Bethlehem Steel Export Corporation



Making "3-in. edge" extrusions with die of Cromo-WV

A manufacturer in the Southeast needed a long wearing hot-work tool steel to produce a "3-in. edge" extrusion made of aluminum. They talked it over with our local tool steel distributor who recommended making the die from a Bethlehem Cromo-WV upset-forged disc.

It was a good choice. The disc machined readily, and was easy to heat-treat. Hardened to Rockwell C47, the die extrudes 24 billets per hour, with brief stops for polishing. The life of the die is about 50,000 lb of extruded metal.

Cromo-WV, with its 5 pct chrome content, plus .30 pct vanadium, is a modification of our popular Cromo-W, the original 5 pct chrome hot-work steel. Resistant to heat checking, Cromo-WV also has good red hardness, and good shock resistance.

Like to give Cromo-WV a try? Just call your Bethlehem tool steel distributor. You'll find he will handle your request promptly.

BETHLEHEM TOOL STEEL ENGINEER SAYS:

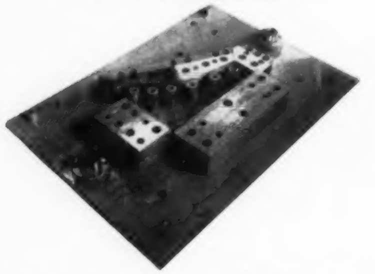
Drilled Holes Are Not Round (Usually)

Round holes which are drilled in tool steel stock with twist drills, if measured accurately, are usually found to be: 1. out of round; 2. oversize (compared with drill diameter); and 3. tapered throughout their depth. In other words a half-inch-diameter hole cannot be drilled with a half-inch-diameter drill.

This condition results largely from mechanical "play" in the drilling equipment, although many other factors can exert considerable influence. For example, if the two ground lips which form the cutting edges of a twist drill are unequal in length, the drill will produce holes of irregular size and shape.

The production of parts containing accurate round holes is most commonly accomplished by rough-drilling the holes undersize, and then either reaming or broaching to obtain the desired size.

Bethlehem Air-4 Is an Ideal Free-Machining Grade



Air-4, Bethlehem's new medium alloy tool steel, is an ideal free-machining grade due to the addition of lead. It hardens in air at 1525F to 1575F, and provides excellent wear and high toughness. Air-4 is also a deep-hardening grade, with high compressive strength. Order it today from your Bethlehem tool steel distributor.

chining cast iron, it averages 11.7 pieces with 0.008-in. wearland.

For further information circle No. 1189 on literature request card, page 48-D.

Radiography

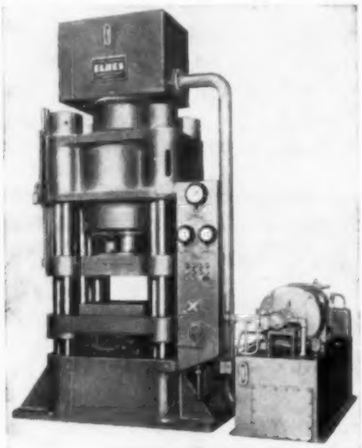
A radioisotope machine that will radiograph steel up to 12-in. thick has been announced by Picker X-Ray Corp.

The Cyclops' sourcehead is capable of handling a cobalt 60 source of 1500 curies. The model pictured is used to radiograph heavy steel castings.

For further information circle No. 1190 on literature request card, page 48-D.

Coining

A new 1000-ton hydraulic coining press for sintered metal compacts that require high unit pressures has been announced by Elmes Engineering Div. It is a single-action press, designed for automatic or semi-automatic cycling. An intermediate moving platen (die holder) is incorporated in the design to provide for "straight through" ejection of the coined compact. This platen is supported above an anvil slide which moves horizontally. During application of pressure to the compact, the anvil is aligned beneath the intermediate platen, serving as a nonyielding base for the die or mold. During ejection, the intermediate unit is raised enough to clear the anvil and die. This permits the coined piece to be pushed through the bottom of the die onto a shuttle. The shuttle, during subsequent cycles of the press, carries each coined compact to the front of the press.



For further information circle No. 1191 on literature request card, page 48-D.

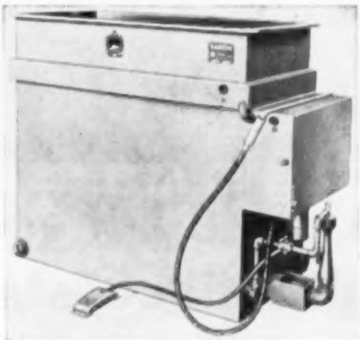
Testing Furnace

A new tensile-testing furnace for operation at 4500° F. in a vacuum of 0.01 to 0.05 microns has been announced by the Vacuum Furnace Div. of Richard D. Brew and Co. A tantalum element 1½ in. diam. by 6 in. high heats the furnace. A tensile specimen can be assembled and disassembled to the grips without moving the furnace.

For further information circle No. 1192 on literature request card, page 48-D.

Degreasing Machines

A new line of vapor spray degreasers has been announced by Baron Industries. The series consists of five models. Interior lengths range from 3 to 8 ft., while the inside depth and width of each size is 24 by 24 in. They use a trichlorethylene vapor solution to dissolve greases, oils and waxes from all ferrous and nonferrous metals. Baronet degreasers will handle a workload of from 1600 to 2000 lb. per hour, depending on size of parts.



For further information circle No. 1193 on literature request card, page 48-D.

Controller

Thermo Electric Co. has announced a new signaling controller for automatic control of industrial operations suitable for two-position control action. It can be used with any transducer generating a d.c. signal, such as thermocouples, tachometer generators or load cells. Corrective action of the controller occurs almost simultaneously with detection of any input signal deviation. It is sensitive enough to react to a change of 1 microvolt.

Calibration accuracy is guaranteed to be within ±0.25% of full scale span or 5 microvolts. The controller comes in ranges from 1 to 100 microvolts.

For further information circle No. 1194 on literature request card, page 48-D.

Finish for Stainless Steel

A new finish giving a frosty appearance to stainless steel has been announced by Allegheny Ludlum Steel Co. Developed by Stamping Service, Inc., the new finish is being used on automobile trim sections. It is made by a semiblasting technique which forms tiny mounds on the surface of the metal. This is done lightly so the surface of the metal is not penetrated, but light rays are diffused giving the frosted appearance.

For further information circle No. 1195 on literature request card, page 48-D.

Cleaning Cutting Oils

A new separator unit for the automatic removal of ferrous solids from cutting oils and other soluble coolants has been announced by the U. S. Hoffman Machinery Corp. It is self cleaning. The Magnaflo separator consists of a tank, magnaplate, baffle and

sludge scraper mechanism. These are combined to utilize magnetic force for the removal of ferrous solids. Flow rates are from 40 to 1000 gal. per min.

For further information circle No. 1196 on literature request card, page 48-D.

Inert-Gas Welding

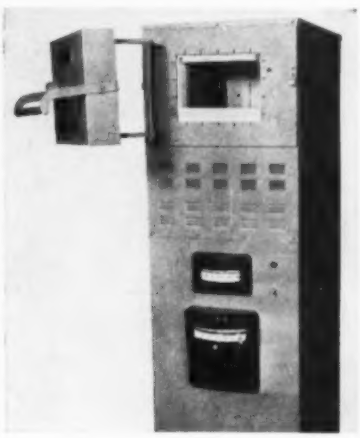
The Lincoln Electric Co. has announced a new Idealarc welder for tungsten inert-gas welding. It also can be used for metallic arc welding. The new model is available in the NEMA rated 300 amp. size either as a straight a.c. transformer welder or as a combination a.c.-d.c. rectifier welder. The welder has a saturable-reactor-type control. Optional features that may be added to either type of welder include: A high-frequency kit complete with controls for water, gas and high-frequency arc intensity; remote hand or foot control for adjusting amperage to fill craters or compensate for variations in the joint; a d.c. filter to eliminate direct current created in the arc when welding with a.c. and high frequency. Electrical circuitry

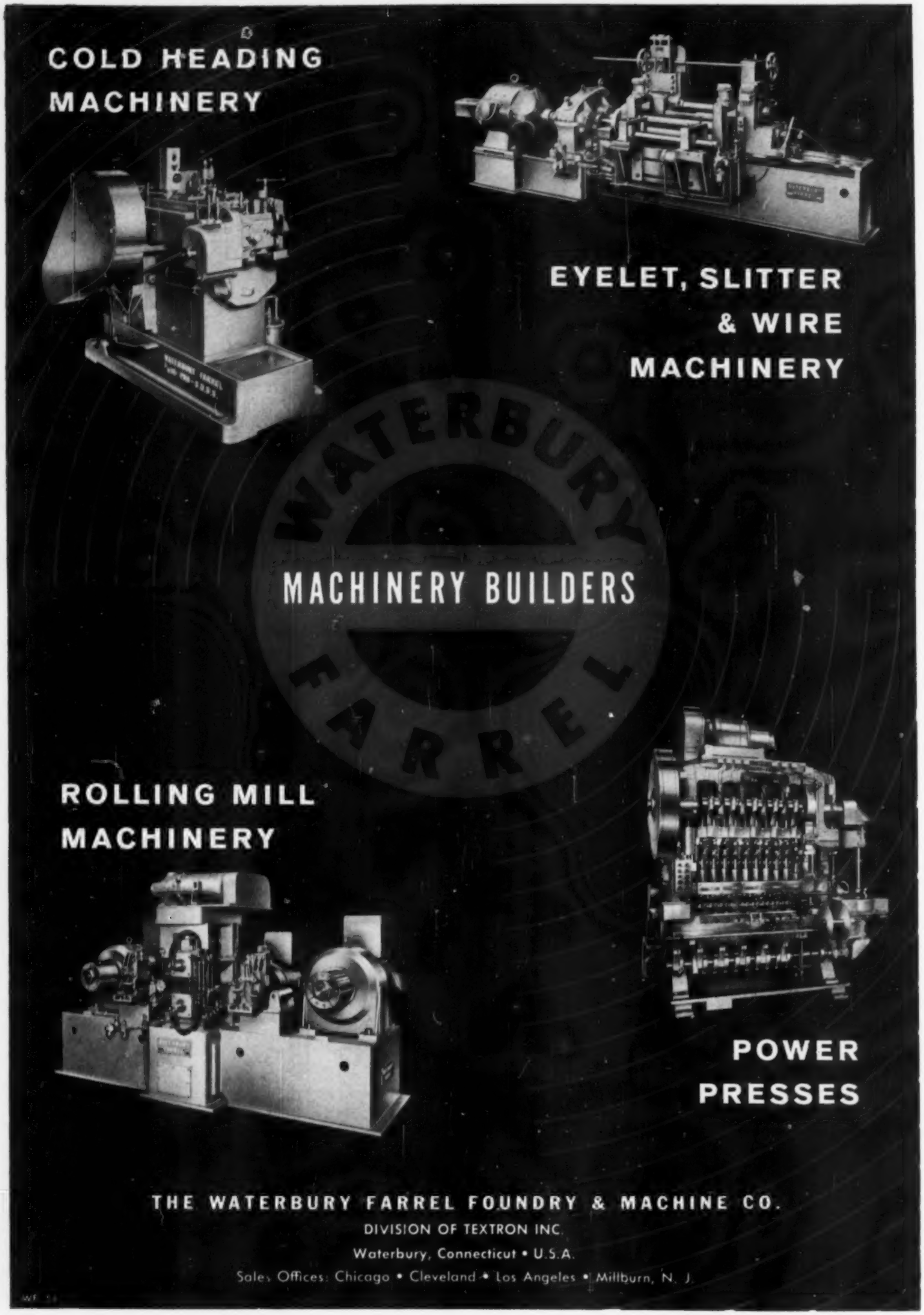
and construction are aimed toward providing sinusoidal-type output current characteristic. This gives the arc maximum cleaning effect on aluminum and fosters faster welding speeds. It also provides good arc characteristics with manual electrodes.

For further information circle No. 1197 on literature request card, page 48-D.

Box Furnace

A new box furnace with a maximum operating temperature of 2250° F. has been announced by the Pilot Plant Equipment Div. of Lindberg Engineering Co. The furnace chamber is 5⅝ in. high, 14¼ in. deep and 8½ in. wide. A metallic packing, recessed in the inner face of the door, eliminates

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EYELET, SLITTER & WIRE MACHINERY
WATERBURY FARREL
MACHINERY BUILDERS
ROLLING MILL MACHINERY
POWER PRESSES
THE WATERBURY FARREL FOUNDRY & MACHINE CO.
DIVISION OF TEXTRON INC.
Waterbury, Connecticut • U.S.A.
Sales Offices: Chicago • Cleveland • Los Angeles • Millburn, N. J.

brick to brick contact and thereby minimizes dusting and heat loss. The furnace is not supplied with atmosphere equipment, but an atmosphere retort is available as an accessory.

For further information circle No. 1198 on literature request card, page 48-D.

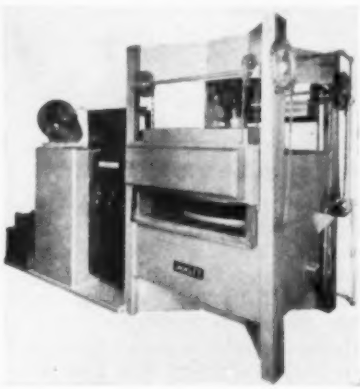
Recorders

New circular chart recorder-controllers, with either electric or pneumatic controls, have been announced by the Daystrom-Weston Industrial Div. of Daystrom, Inc. All models feature the D-Pak constant - voltage supply unit. The new recorders are designed for a.c. operation only on 115 v., 60 cycles or 115 v., 50 cycles, as specified. The 12-in. chart has full-scale pen travel of 4⅝ in. Response time is 5, 10 and 20 sec. and chart speeds are 7 days, 48, 24, 12, 8, 4 or 1 hr. per revolution.

For further information circle No. 1199 on literature request card, page 48-D.

Recirculating Furnace

Waltz Furnace Co. has announced flattening and tempering furnaces for heat treating large, thin, circular

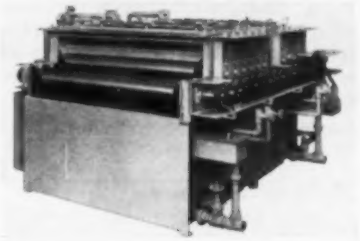


pieces such as circular saws. Work is placed in the chamber between two 42-in. circular cast iron dies. The furnace is gas-fired. Temperatures range from 350 to 1000°F. The burner fires into a combustion chamber on the inlet side of the recirculating fan. The combustion blower is mounted on top of the air duct, to the left of the control panel.

For further information circle No. 1200 on literature request card, page 48-D.

Washing Machine

The Alvey-Ferguson Co. has announced a new cleaning machine which will automatically wash, rinse and dry 4 ft. sq. sheets of heavy metal plate.



Power-driven rolls advance the plate through all operations. The upper rolls are individually spring loaded to adjust tension. Cleaning and rinsing are accomplished by power spraying the solution (and later the rinse water) and brushing with power-driven rotating brushes.

For further information circle No. 1201 on literature request card, page 48-D.

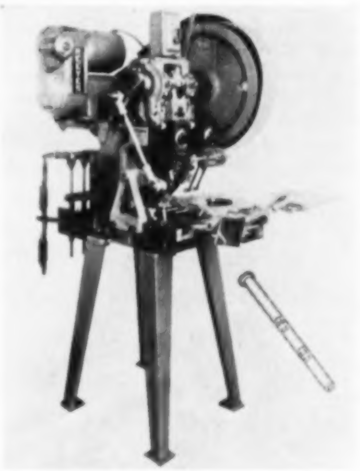
Temperature Control

Saturable reactors for controlling and regulating the temperature of electric furnaces have been announced by the Sorgel Electric Co. The reactors permit control of a.c. power from 1 to 300 kva., single-phase or three-phase, at any voltage. Voltage can be controlled, regulated and varied in stepless increments. The unit consists of a laminated steel core and a series of coils similar to a transformer, in which the core is magnetized and saturated to a varying degree by d.c. current. It contains no moving parts except the small contacts in the control device.

For further information circle No. 1202 on literature request card, page 48-D.

Stamping

An improved hot stamping machine that has two marking heads, is driven by a variable-speed motor and utilizes an improved dial feeding system has been announced by the Acromark Co. The dual hot stamping heads have individual dwell controls and indi-

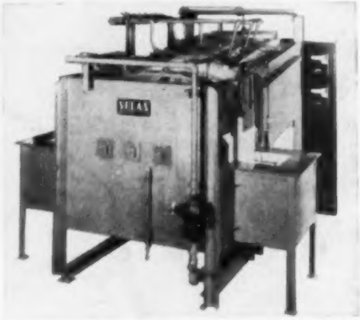


vidual pressure controls so that they may be used for marking with two colors at the same time. Each head is self-leveling. Speeds up to 4500 parts per hour can be attained.

For further information circle No. 1203 on literature request card, page 48-D.

Melting Furnace

A new dry-hearth furnace for melting electrical-quality aluminum has been announced by Selas Corp. Both dry and wet sections of the furnace are roof-fired with Duradiant burners



that eliminate direct flame impingement, avoid contamination of the aluminum and provide close control of heat input. A special lining in the furnace also minimizes contamination.

For further information circle No. 1204 on literature request card, page 48-D.

Cleaning

A new Uniflo nozzle for shot, grit and sand blasting has been announced by W. M. Sly Mfg. Co. The nozzle is lined with tungsten carbide; the jacket is of Kirksite. Orifice sizes are 3/16, ¼, 5/16, ⅜, 7/16, ½ and ¾ in. Nozzles can be used in hand blasting, cabinet and barrel operations.

For further information circle No. 1205 on literature request card, page 48-D.

Swaging

The Fenn Mfg. Co. has announced a new automatic feeder and unloading accessory for swaging machines. Each piece is gravity loaded into the feeding mechanism where it is automatically gripped and fed into the swager. After the swaging operation, it is retracted and the piece automatically ejected. Simultaneously, another piece

is fed into the machine. This accessory should increase the potential of any swager as a production machine.

For further information circle No. 1206 on literature request card, page 48-D.

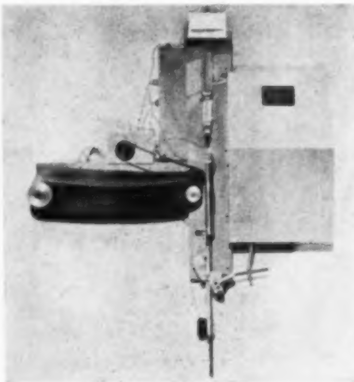
Corrosion Prevention

A new liquid additive to hot water rinses which prevents spotting and subsequent corrosion of metals has been announced by Enthone, Inc. The new product causes rinse water to shed rapidly from the metal surface resulting in faster drying and elimination of water spots and stains. Entek 45 may be used after plating, pickling, or chemical processing of any kind.

For further information circle No. 1207 on literature request card, page 48-D.

Marking Machines

Automatic, high-speed machines that employ the electrolytic marking process have been announced by the Electromark Corp. Three marking methods are available: plating, etch-



ing, and a.c. or oxide mark. The machine shown is typical of those built for marking of saw blades, cutlery, electronic parts, engine parts, gages, bearings, drills and other small smooth-surfaced products.

For further information circle No. 1208 on literature request card, page 48-D.

Welding Alloy

A new resistance welding alloy of copper and zirconium has been developed by the Metallurgical Div. of P. R. Mallory & Co., Inc. Mallory 28 metal has high electrical and thermal conductivity coupled with high strength and hardness. Properties are developed through a combination of cold working and heat treatment. It is recommended for spot and seam welding of aluminum and magnesium alloys, and steels having low-melting-point coatings, such as galvanized, aluminized, terne plate, tin plate and cadmium plate.

For further information circle No. 1209 on literature request card, page 48-D.

Progress Report on

TWO NEW METHODS OF TUBULAR COMPONENTS PRODUCTION

Special metal-working techniques are being used by the Tapco Group to produce tubular members with distinct advantages for hundreds of aircraft, missile, industrial and consumer-product applications. Two of these techniques, Metal Gathering and Flotrusion*, offer important solutions to designers and engineers with the problem of tubular parts production.

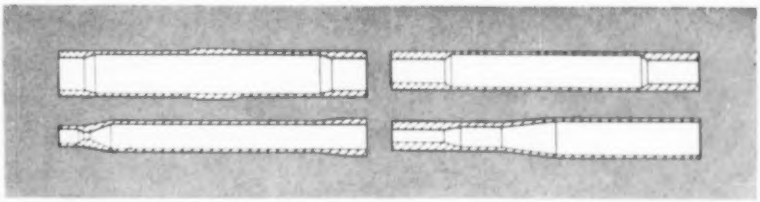


Figure 2—Flotrusion produces any desired variation in metal tubing, including those illustrated here.

METAL GATHERING

Using the Metal Gathering process, a portion of a metal tube is heated in a resistance unit, then "gathered" into a forged lump or mass at either or both ends of the tube. The heated end-mass can then be immediately extruded or forged to any desired rough configuration. After gathering or forging, any machining operation needed to finish the end is readily done right in the shops of the Tapco Group. Examples of tubing end-features produced by this process are illustrated in Figure 1.

Metal Gathering by the Tapco method offers several advantages: one-piece parts free from welds, brazing, or mechanical assembly; minimum machining for end features; no machining of tube interior to reduce wall thickness; better grain flow for greater strength and fatigue resistance; uniform heat-treatment because the whole part is formed from tubing; heavy sections are integral with tubing; no excess metal required, hence material cost is less; a rapid process for reproduction once tooling is established.

*Reg. Trademark – Used under License from Flotrusion, Inc.

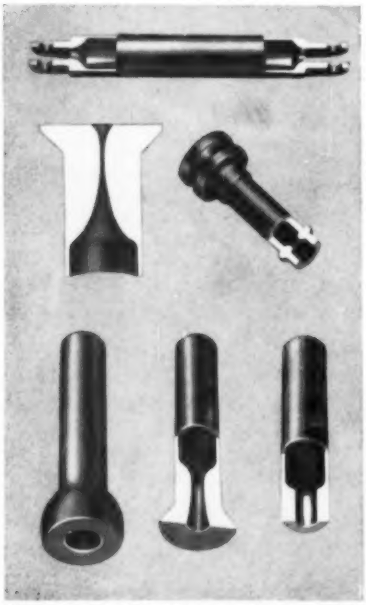


Figure 1—Typical end-features that are readily produced in tubing by the Tapco Group using the versatile, cost-saving Metal Gathering process.

The Tapco Metal Gathering process is readily applied to any metal, including steel, stainless steel, aluminum, titanium, and zirconium.

Designs are almost unlimited in size, complexity, and features. A broad range of tubing lengths, diameters, and wall thicknesses can be handled by the Metal Gathering process. Close tolerances can be supplied; grinding, polishing, or honing can be vastly reduced, and in some cases eliminated. One-piece parts replace multi-part assemblies. The process can also be used at various points along the length of the tubing.

FLOTRUSION

The Tapco Flotrusion process permits cold-drawing of tubing into various internal and external thicknesses, configurations, sizes, and shapes, shown in Figure 2. The process was developed to permit high-production rates of parts normally employing high-cost machining or polishing. Flotrusion can also be combined with the Tapco Metal Gathering process to produce an almost limitless variety of end-features, wall-thickness variations, and other features in tubing.

Tapco Flotrusion offers these advantages:

Heavy wall sections can be developed at one or both ends of cylindrical forms to provide for bearings, threads, or weldments,

Uniform wall thickness can be provided with smaller or larger diameters on the tube,

Surface finishes of excellent quality are standard, without expensive machining or polishing,

Burring and honing are not required,

Grain structure is improved, and additional heat-treatment can often be eliminated since cold-working improves tensile strength,

Tubing that has been heat-treated before Flotrusion gains added strength by cold-working,

Non-heat-treatable metals also gain strength by the cold-work effect of Flotrusion,

No excess material is required . . . Flotrusion requires only the exact volume of material that the finished part requires. Material cost is kept down.

All forgeable metals can be processed by Flotrusion . . . alloy and stainless steels, aluminum, titanium, zirconium, and others.

Tube diameters from 0.060" to 10" can be worked on present Flotrusion equipment at Tapco's completely-equipped plant. Lengths to 15 feet have been processed, but longer lengths and larger diameters are within the range of Tapco capabilities and facilities.

The configurations shown will give you ideas of how you can reduce the cost of tubular components by Metal Gathering or Flotrusion or a combination of the two. A 16-page design and data book on both processes will be sent to you on request.

TAPCO GROUP

Thompson Ramo Wooldridge Inc.

TRW

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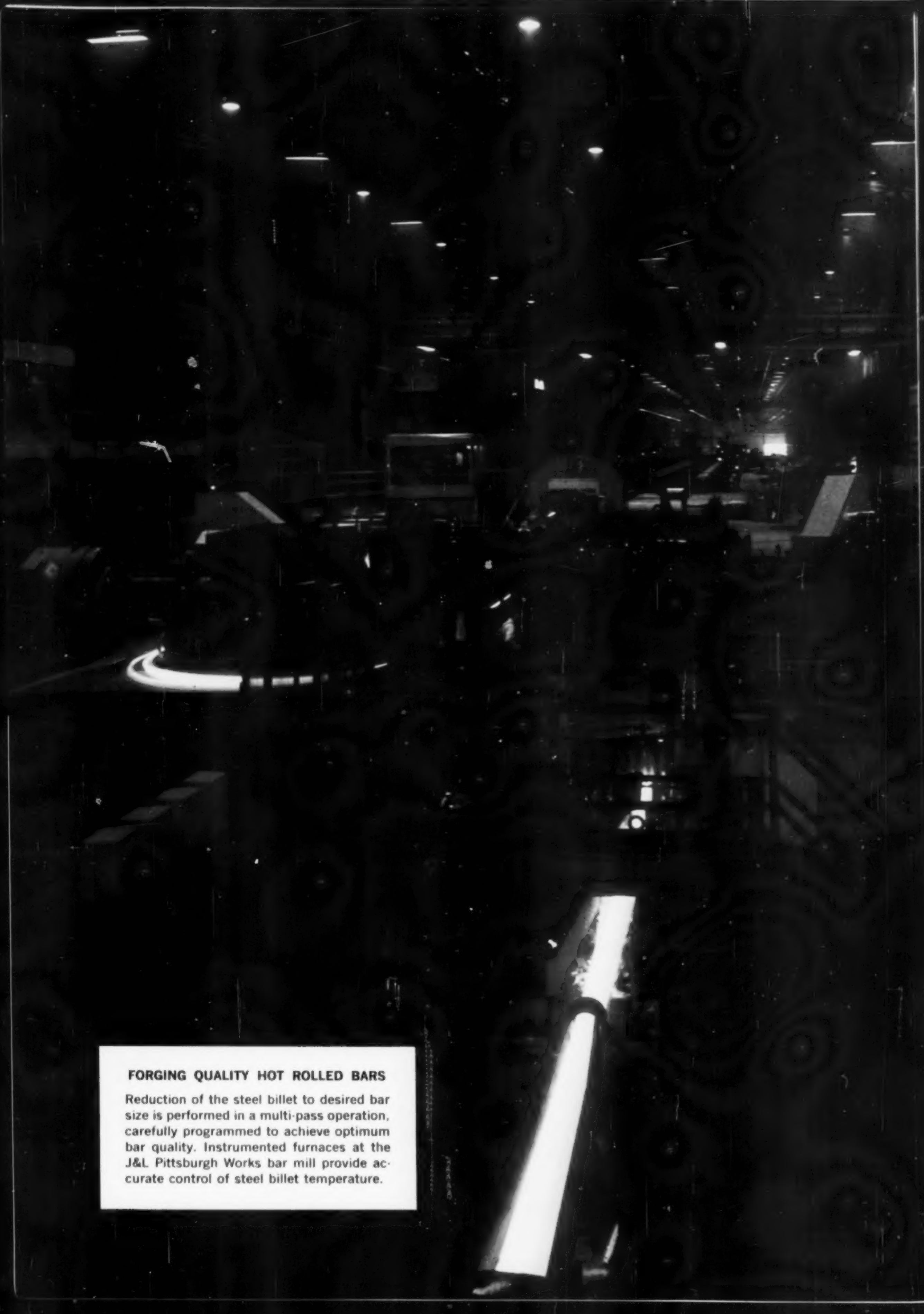
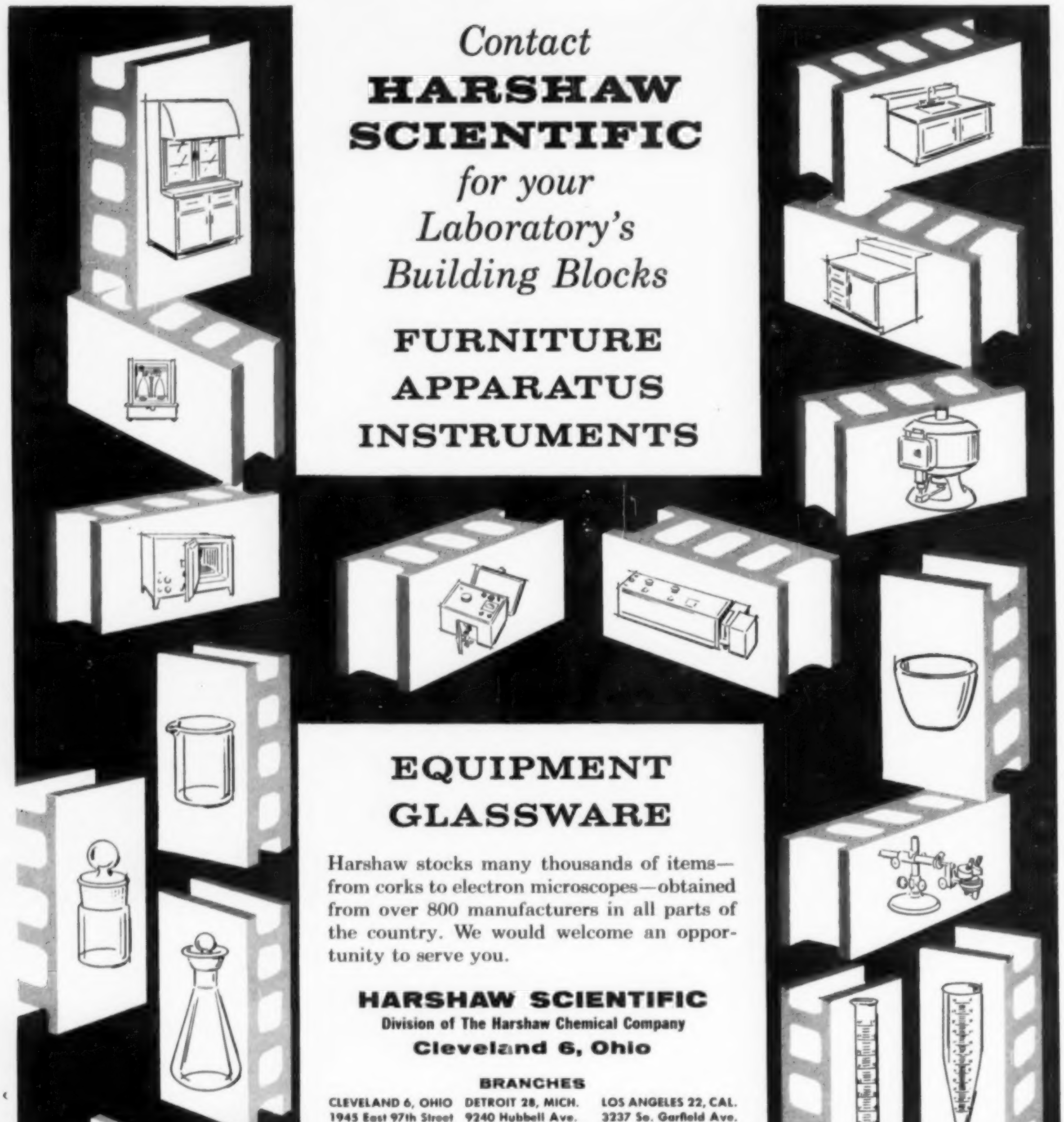


FORGING QUALITY HOT ROLLED BARS

Reduction of the steel billet to desired bar size is performed in a multi-pass operation, carefully programmed to achieve optimum bar quality. Instrumented furnaces at the J&L Pittsburgh Works bar mill provide accurate control of steel billet temperature.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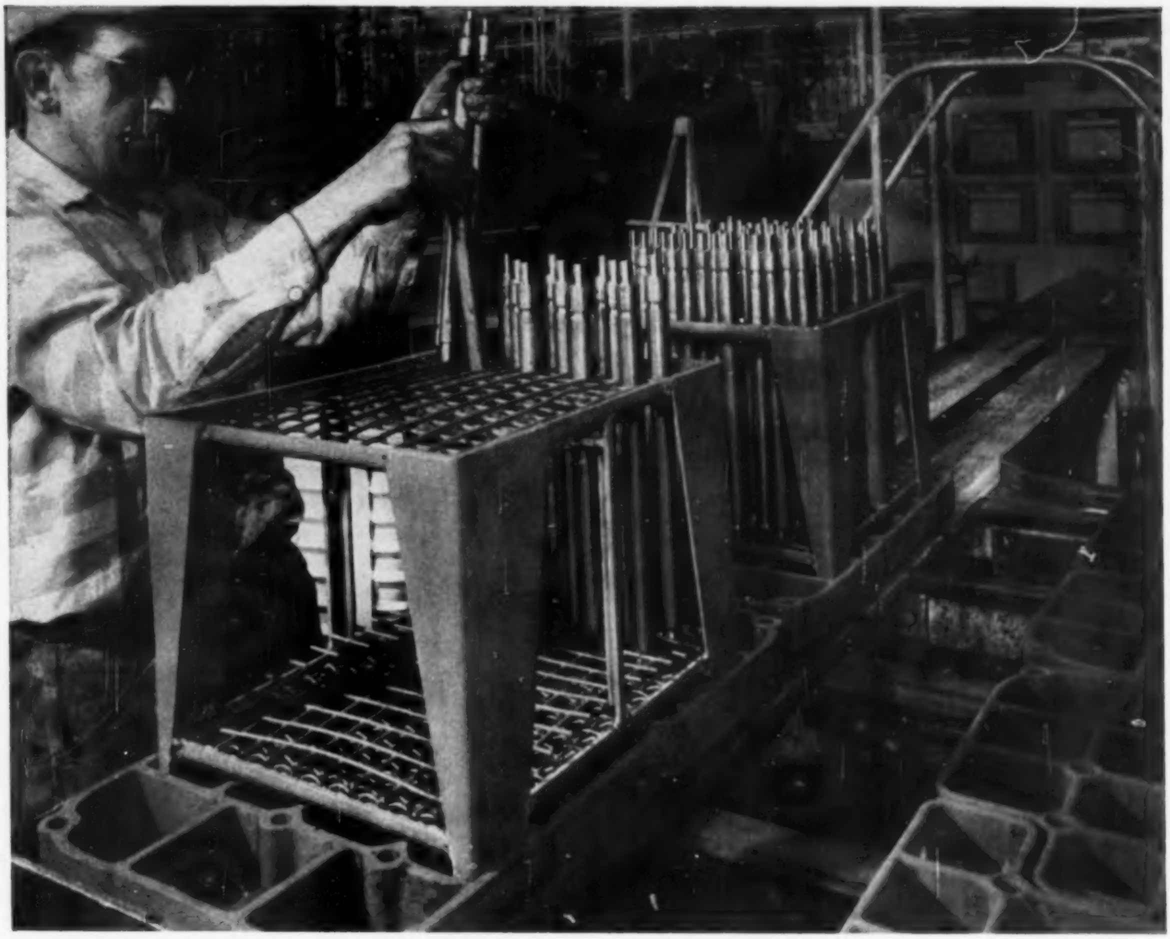

Workman loads light-weight, long lasting Incoloy fixture with 58 shafts in carburizing cycle. Fixture design and Incoloy alloy have proven to be so practical that this large auto engine plant has standardized on them.

INCOLOY fixtures in 1650°F carburizing cycles stand up for 12 months 'round the clock

A year's continuous carburizing work – still in good condition.

That's the life obtained with these Incoloy* nickel-iron-chromium alloy heat treating fixtures. Fixtures hold shafts upright during 1650°F carburizing followed by 160°F oil quenching.

Incoloy alloy is particularly resistant to carburizing conditions; gives such fixtures as this excellent high temperature strength, excellent resistance to corrosion and thermal shock. Sound welds are made with Inco #132 Electrodes. Fabricators such as Rolock can engineer and produce an unlimited number of practical, economical designs.

For more information, quotations on these fixtures, write Rolock, Incorporated, Fairfield, Connecticut. For more information on Incoloy alloy, write Inco.

*Registered trademark

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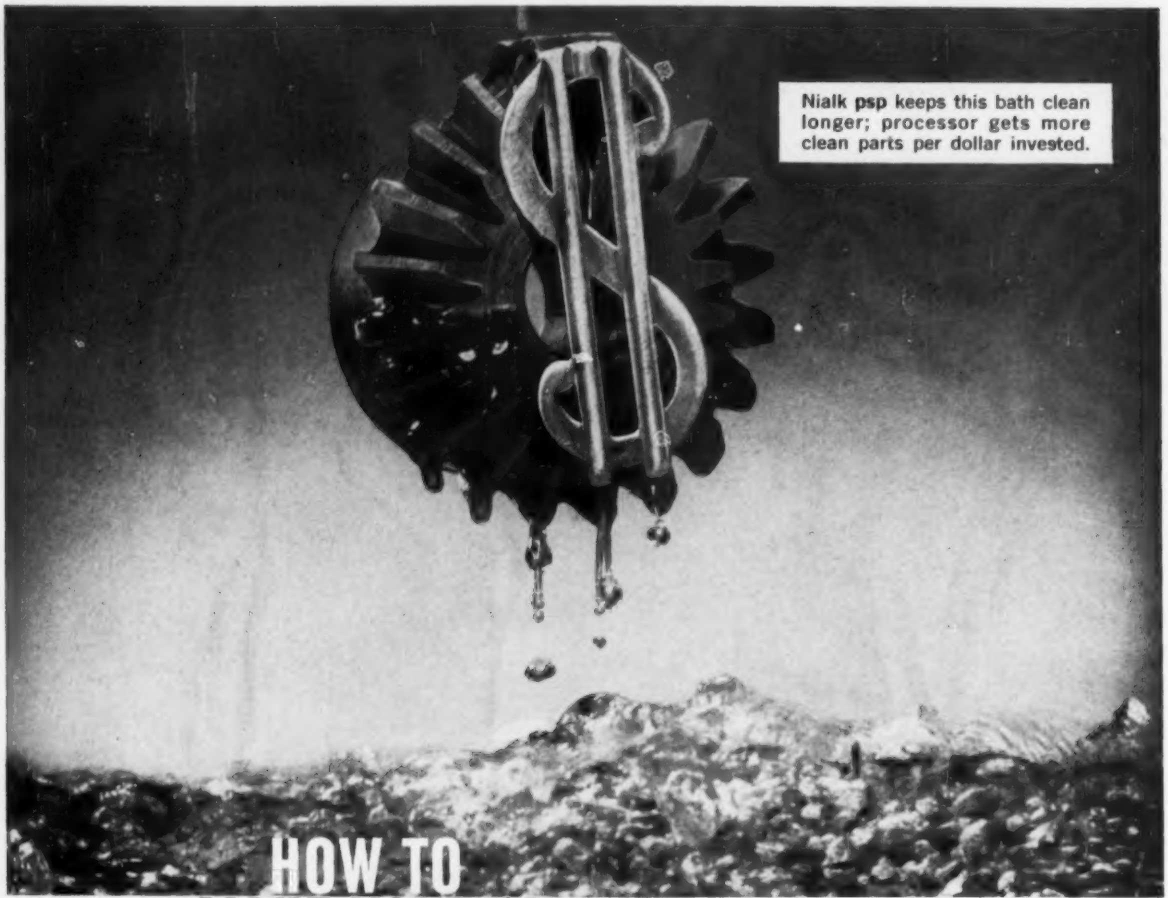
INCO NICKEL ALLOYS



HOW TO MAKE YOUR $'s DEGREASE MORE PARTS

You make no profit on the time you spend cleaning out a degreaser.

You cut another slice off the top of profits whenever you have to add fresh stabilizer to your trichlorethylene bath.

When a bath goes "sour" while you're processing, you lose still more time and money.

psp is the simple answer

Trichlor is trichlor the world over; it's the *stabilizer* in your trichlor that can make the difference.

The difference in Nialk® stabilizer is *psp*—permanent staying power.

Nialk stabilizer is neutral. It cannot react with acids to form corrosive salts. Still it "accepts" acids and renders them completely harmless. The Nialk stabilizer will not stain or discolor your parts or allow your bath to become "sour."

You never add fresh stabilizer to a Nialk bath. The stabilizer stays potent no matter how long you use it. It's insoluble in water so you don't lose it during steam distillation or in the water separator of your degreaser.

Nialk frees your bath of those degradation products which settle on coils and cut down heat transfer. Cleanouts are widely spaced and quickly finished.

If your profit picture could use a little brightening, you'll want to know more about the whole subject of trichlor stabilizers. Send for our Bulletin 70 for the complete story.

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THE ONES THAT WILL LAST (and last, and last!)? THOSE MADE OF WEIRKOTE® ZINC-COATED STEEL!

Laboratory salt-spray tests prove it. Leading manufacturers prove it. Experience proves it. Primary window frames and storm and screen frames of Weirkote zinc-coated steel last and last and last—literally shrug off the elements!

Weirkote will not give in to corrosion invasion because its zinc coat clings tightly to its steel surface year after year. Reason? Zinc and steel are actually integrated by Weirkote's continuous process.

This extra protection pays off when it comes to fabricating Weirkote, too. You can crimp it, twist it, torture it—work it to the limits of the steel itself—without chipping or flaking its surface. And this pays off in your pocketbook: No more costly rejects, and coating after fabrication can be eliminated.

Whether you're talking profit or product, there's a lot to be said for Weirkote zinc-coated steel. Write today for a free booklet that tells all about it. Weirton Steel Company, Dept. S-14, Weirton, West Virginia.

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APPLICATION and EQUIPMENT new literature

1211. Abrasives
New catalog covering SAE specifications on all types of abrasive shot, grit and cut wire. Methods and advantages of shot peening and impact cleaning, and the proper abrasive mixtures. *Cleveland Metal Abrasive*

1212. Alloy Steel
16-page book on type 9115 low-alloy high-strength steel. Properties, fabrication, welding. *Great Lakes Steel*

1213. Alloy Steel
12-page data sheet on Hy-Tuf alloy steel. Composition, properties, annealing. Hardenability band. TTT curves, bend tests. *Crucible Steel Co.*

1214. Aluminum
24-page data book on high-strength aluminum-zinc-magnesium-chromium-titanium alloy. Properties, aging, corrosion. *Frontier Bronze*

1215. Aluminum
8-page bulletin on aluminum casting alloys. Properties; selection of casting method; pig, ingot and billet compositions. *Metals Div., Olin Mathieson Chemical Corp.*

1216. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

1217. Aluminum Extrusions
Folder lists alloys used, finishes, trade phraseology. *General Extrusions*

1218. Aluminum Extrusions
Catalog of extrusion dies in stock. *Jarl Extrusions*

1219. Atmosphere Furnace
New Bulletin 865 on controlled atmosphere, continuous rotary retort furnace describes operation and construction. *American Gas Furnace*

1220. Atmospheres
New Bulletin I-107 supplies technical information on inert gas generators. Specifications. Composition of gases. *C. M. Kemp*

1221. Beryllium
12-page bulletin on physical constants, mechanical properties, thermal properties and forms in which beryllium is available. QMV process of beryllium production. *Brush Beryllium Co.*

1222. Bimetal Applications
44-page booklet, "Successful Applications of Thermostatic Bimetal", contains uses, formulas, calculations. *W. M. Chace*

1223. Black Oxide Coatings
8-page booklet on black oxide coatings for steel, stainless steel and copper alloys. *Du-Lite Chemical Corp.*

1224. Blast Cleaning
Complete information on Malleabrasive for cleaning and finishing. *Globe Steel Abrasive*

1225. Blast Cleaning
New 24-page Bulletin 100C on blast cleaning hose machines. Selection and uses. *Pangborn Corp.*

1226. Brazing
52-page Publication GEA-3193C on how and where to use electric furnace brazing. Limiting creep of brazing metal, selecting the brazing metal, strength of furnace-brazed parts, how to braze cast iron. *General Electric*

1227. Brazing
8-page reprint on production brazing illustrates items produced and how they are made. *Selas Corp.*

1228. Burners
Bulletin 214 on dual-fuel burner for ovens, kilns, driers, forge furnaces, heat treating and malleabilizing furnaces. *North American Mfg.*

1229. Carbides
New 32-page catalog on line of tungsten carbide tools, tool tips, dies, wear parts. *Adamas Carbide Corp.*

1230. Carbon and Graphite
20-page catalog on carbon and graphite applications in metallurgical, electrical, chemical, process fields. *National Carbon*

1231. Carbon Control
Bulletin SC-168 on system for automatically controlling carbon potential in continuous and batch furnaces. *Surface Combustion*

1232. Carburizer
Data sheet on Perliton 400, water soluble carburizer. Operation of bath. Case depths. *E. F. Houghton & Co.*

1233. Casehardened Steel
8-page Catalog No. 2 on hardened and ground shafts, rolls, guide rods and other long round parts. *Thomson Industries*

1234. Castings
Literature on shell or sand castings of ArmaSteel, malleable iron or gray iron. *Central Foundry Div.*

1235. Castings
Brochure on plaster mold castings of brass, bronze, aluminum, beryllium copper. *Ohio Precision Castings, Inc.*

1236. Centrifugal Castings
8-page brochure gives properties of most common grades of thermalloy centrifugally cast tube. Weight tables. *Electro-Alloys Div.*

1237. Chemicals
22-page bulletin on industrial chemicals lists those available and illustrates their manufacture and testing. *Harshaw Scientific*

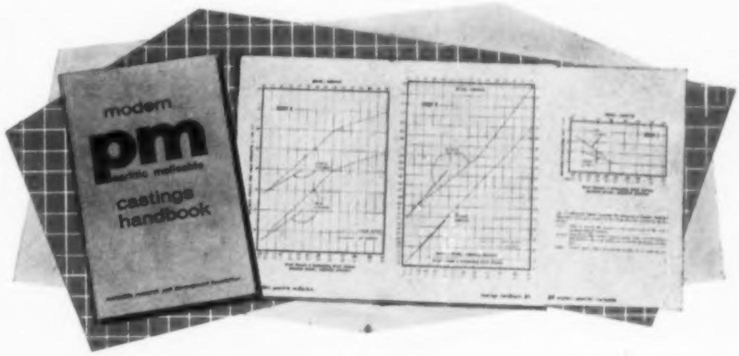
1238. Chill Treatment
Case histories of experience in chilling metals at −130 to −150° F. for stabilization and controlled ductility. *Harris Refrigeration Co.*

1239. Chromate Finishing
File on chromate conversion coatings for prevention of corrosion and paint-base treatment of nonferrous metals. *Allied Research Products*

1240. Chromium Stainless
12-page book on fabrication and use of Type 430 stainless steel. *Sharon Steel*

1241. Clad Metals
12-page catalog on clad metals, thermostat metals, electrical contacts, filled and rolled gold plate. *General Plate Div., Metals and Controls*

1242. Coatings
4-page catalog on heat-proof protective coatings. Basic types, applications, meth-



1210. Pearlitic Malleable Iron Castings

A solid technical book, 74 pages, hard bound. Summarizes engineering and design information clearly and concisely. Of particular interest is the fold-out insert showing minimum tensile properties as a function of Brinell hardness, and the normal Brinell range for each level of specified minimum Brinell, for both air-quenched and liquid-quenched castings. (See cut above.) Applications are well covered. Glossary, bibliography and index have been compiled with evident care. *Malleable Research and Development Foundation*

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between 0.4 mc and 10.0 mc.
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ods of applying and temperature ranges. *Markal Co.*

1243. Cold Header
Bulletin on solid die double stroke cold header. Design features. Advantages of toggle-type construction for actuating heading gate. *Waterbury Farrel Foundry & Machine*

1244. Controlled Atmospheres
Bulletin 753 on generator for atmospheres for hardening, brazing, sintering and annealing carbon steels. *Hevi Duty*

1245. Corrosion-Resistant Alloy
16-page booklet gives chemical, physical and mechanical properties, high-temperature properties, and a guide to corrosion resistance for Hastelloy "C". *Haynes Stellite*

1246. Creep Testers
Pocket-size creep load calculator that determines the pounds of weight needed on weight pan when testing specimens in creep testers. *Arcweld Mfg. Co.*

1247. Creep Testing
10-page Reprint M-1 on tensile and creep properties of tungsten at elevated temperatures. *Instron Engineering Corp.*

1248. Creep Testing
Data sheet on stress rupture and creep testing machine. Operation, calibration, maintenance, specifications. *Tinius Olsen*

1249. Cutting Oil
Folder describing nine types of cutting oils for varied applications. *Gulf Oil*

1250. Degreasers
Catalog No. 10M 359 on standard and special vapor degreasers and industrial ovens. *Baron Industries*

1251. Degreasing
Booklet on vapor degreasing. Design, installation, operation and maintenance of equipment. *Circo Equipment*

1252. Degreasing
40-page book on trichlorethylene gives specifications, properties, uses, handling and storage, toxicity and safety measures. *Hooker Chemical Corp.*

1253. Disintegrators
Catalog B-1 on disintegrator which will remove embedded broken tools. Specifications. *Jiffy Disintegrator*

1254. Dryer
Bulletin 130 describes Aero aftercooler for removing moisture from compressed air and gas. Application of equipment. *Niagara Blower Co.*

1255. Electric Furnaces
Data sheet describes and gives specifications of standard nonmetallic resistor furnaces. *Harrop Electric Furnace Div.*

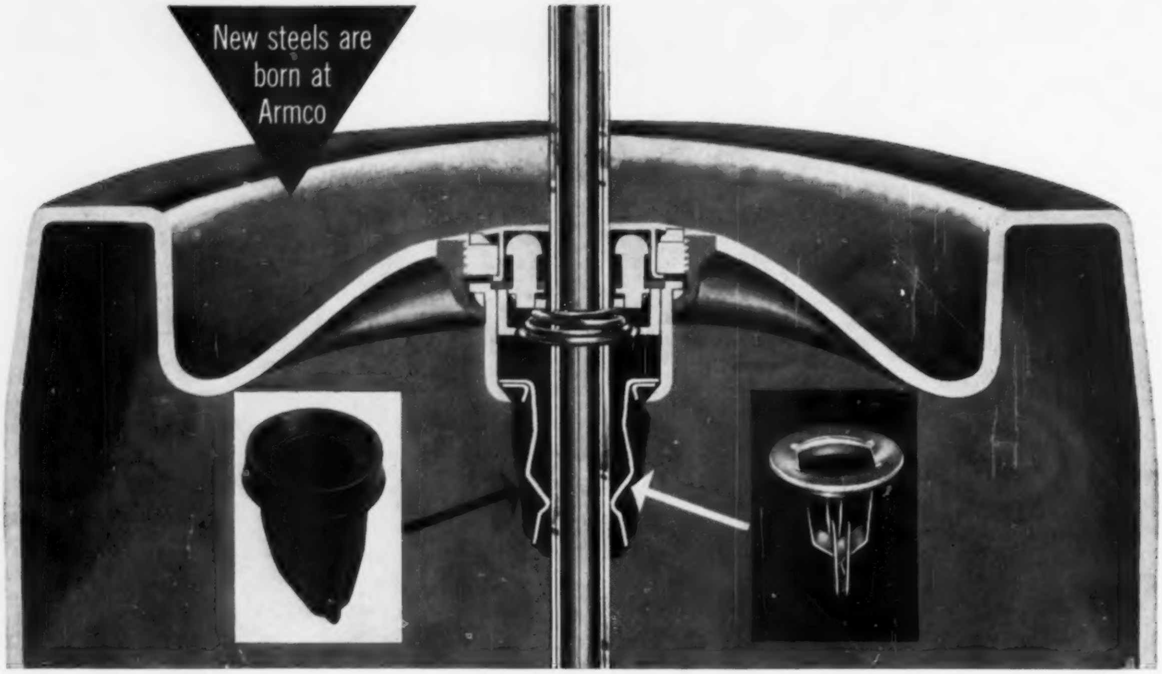
1256. Electric Furnaces
Bulletin 441 on box-type electric furnaces diagrams and describes the furnaces and lists specifications. *Hevi Duty*

1257. Electrolytic Machining
New Bulletin No. 130 on resharpening milling cutters by electrolytic removal. How to install equipment. *Anocut Eng.*

1258. Extrusions
Booklet describes advantages of Cold-Prest impact extrusions, design considerations and methods of production. Alloys used. *Mueller Brass*

1259. Fabrication
Booklet on welded steel heavy fabrication pictures and describes how various products are made. *R. C. Mahon*

1260. Ferroalloys
New 4-page folder on Chromtemp exothermic ferrochromium. Advantages, selection of analysis and grades. *Union Carbide Metals*



How Seal Spring of Special Armco Stainless
Helps Keep Draft Beer Fresh

An unrelenting "squeeze" from a spring clamp made of special Armco 17-7 PH Stainless Steel helps this new beer keg seal maintain a leak-proof barricade against contamination.

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Corrosion resistance is another top advantage of precipitation-hardening Armco 17-7 PH Stainless. This, combined with its strength and ease of fabrication, accounts for the growing use of this special grade for exacting spring applications.

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ARMCO

Armco Division • Sheffield Division • The National Supply Company • Armco Drainage & Metal Products, Inc. • The Armco International Corporation • Union Wire Rope Corporation • Southwest Steel Products

1261. Finishing Aluminum
Aluminum finishing manual on cleaning, deburring, etching, deoxidizing, descaling, preparation for welding and anodizing; treatment of corroded stock. *Frederick Gumm Chemical Co.*

1262. Flame-Cutting
New 6-page Bulletin 1174 describes manual and machine flame-cutting equipment. *Linde Co.*

1263. Flame Hardening
20-page catalog on flamatic hardening machines and allied equipment. *Cincinnati Milling Machine Co.*

1264. Flow Meters
Bulletin 203 on flow meters for gas used in heat treating. *Waukee Eng'g.*

1265. Forgings
12-page booklet on how forged weldless rings and flanges are made. Case histories. *Standard Steel Works Div., B-L-H*

1266. Forgings
Folder on facilities for production of flat-die forged products. Electronic equipment used. *Smith-Armstrong*

1267. Forgings
Handsome 32-page brochure on large forgings for turbine shafts, rotors, drop hammer anvils, rolls. *U. S. Steel*

1268. Formed Shapes
Catalog No. 1053 describing numerous formed shapes made from ferrous and nonferrous metals. *Roll Formed Prod.*

1269. Freezer
Data on chest for use down to −140° F. for production and testing. *Revco*

1270. Furnace
Bulletin on basic principles of electric furnace design. Cutaway models of 8 furnaces. Cost factors. *Holcroft*

1271. Furnace Belts
44-page catalog describing metal belts for quenching, tempering, carburizing and other applications. *Ashworth Bros.*

1272. Furnace Controls
Bulletin 658 on saturable reactor for regulation and control of electric ovens and furnaces. *Sorgel Electric Co.*

1273. Furnace Fixtures
16-page catalog on baskets, trays, fixtures and carburizing boxes for heat treating. 66 designs. *Stanwood*

1274. Furnaces
12-page reprint on design, construction and application of chain belt conveyor furnaces. *Electric Furnace Co.*

1275. Furnaces
Bulletin on graphite tube furnaces for temperatures to 5000° F. Operating limitations, auxiliary and control equipment. *Harper Electric*

1276. Furnaces
12-page catalog on electric heat treating furnaces. Data on each of 57 models. Controls, instruments, elements and accessories. *Lucifer Furnaces, Inc.*

1277. Galvanized Steel
New 34-page booklet on zinc-iron alloys. Fabrication, how to weld and solder, typical uses. *Armco*

1278. Gas Analysis
52-page Catalog 84 on more than 134 instruments and accessories for gas and vapor chromatography. 158 different listings of partitioning agents. Gas and vapor chromatography. *Burrell*

1279. Gold Plating
Folder gives data on plating to obtain a hard bright gold finish. *Technic*

1280. Gold Plating
8-page brochure gives bath composition, equipment and operating conditions, and

METALGRAMS

. . . news about metals and metal chemicals

UNION CARBIDE METALS

Electromet ferroalloys, pure metals and metal chemic

Slip-casting -- a method almost as old as the potter's wheel for shaping ceramics -- may help solve some modern metal fabricating problems. At the Metals Research Laboratories of Union Carbide Metals Company, tungsten, molybdenum disilicide, and other intractable metals and intermetallics are being slip cast into intricate shapes with close tolerances. The ease with which powdered molybdenum disilicide can be slip cast, for instance, suggests its use as a structural material in missiles and rockets. High temperature oxidation, resistance and a high melting point (2030°C: 3686°F) qualify this refractory material for hypersonic vehicle applications. For more information on molybdenum disilicide write for Bulletin MD 1-M.P.

* * *

The largest columbium ingot ever formed, made from ELECTROMET columbium, was recently melted by the Refractomet Division of Universal-Cyclops Steel Corporation. Weighing 345 pounds, the ingot measured 19 inches long and 9 1/2 inches in diameter. This has been successfully rolled into sheets as long as 170 inches, in widths from 16 to 36 inches, and in gauges from 0.02 to 0.06 inches. Thinner gauges are in prospect. This joint effort effectively demonstrates the feasibility of producing columbium on a commercial scale. Write for Bulletin CB 1-M.P.

* * *

Among new industrial metal chemicals available from Union Carbide Metals are vanadium dichloride, vanadium trichloride, vanadium oxytrichloride, and vanadium tetrachloride. The polyolefin industry is evaluating these high purity compounds in producing new synthetic rubber products. The pharmaceutical industry, also, is studying them as reducing agents in organic reactions. Highly reactive, the vanadium chlorides can also be used to manufacture organometallic compounds. Union Carbide Metals' technical background and experience with vanadium metal -- over a ten-year period -- give investigators in this area a distinct advantage. Write for Bulletin MC 1-M.P.

* * *

Union Carbide Metals Company has begun production of titanium carbide on a semi-commercial scale. This high-melting-point compound has several known and potential applications. As an important additive in tungsten carbide cutting tools, titanium carbide improves resistance to oxidation and erosion. It is also being used for high-speed cutting tools as a base material in cermet compositions. Titanium carbide's resistance to corrosion by molten aluminum and cryolite recommend it as a potential cathode material in aluminum reduction cells. The Company also produces titanium metal and several other titanium compounds. Write for Bulletin TC 1-M.P.

* * *

Demand mounted during 1958 for vanadium metal with low content of oxygen, nitrogen, and carbon. The major contribution to the increased demand for vanadium were A. E. C. applications. Notable quantities, however, are also being used as melting stock in vacuum melting. Write for Bulletin VM 1-M.P.

* * *

A large boule of transistor-grade silicon, produced by General Electric from ELECTROMET purified silicon, was exhibited recently at the Western Metal Exposition in Los Angeles. This boule, measuring 4 in. long by 1 in. max. diam. and weighing 2 3/8 oz., contained enough silicon to make several thousand transistors. Write for Bulletin SM 1-M.P.

* * *

Union Carbide Metals Company, Division of Union Carbide Corporation, P.O. Box 330, Niagara Falls, N. Y.

metallurgical characteristics of 24K gold plate on various base metals. *Sel-Rex*

1281. Graphite
New 12-page booklet on "The ABC's of Colloidal Dispersions". Answers to questions most frequently asked about colloids. *Acheson Colloids Co.*

1282. Hard Facing
8-page engineering data Bulletin 136A on wire and powder sprayed coatings. Basic characteristics. Mechanical and electrical-electronic applications. *Metallizing Engineering Co.*

1283. Hardness Numbers
Pocket-size table of Brinell hardness numbers. *Steel City Testing*

1284. Hardness Tester
20-page book on hardness testing by Rockwell method. *Clark Instrument*

1285. Hardness Tester
Bulletin on how to test large gears with portable Brinell tester. *King Tester*

1286. Hardness Tester
Data on portable hardness tester with Rockwell and Brinell scales. *Mechanical Devices*

1287. Hardness Tester
Catalog 72-1 on Leitz miniload tester for Vickers and Knoop hardness tests. *Opto-Metric Tools, Inc.*

1288. Hardness Tester
Bulletin S-33 on vertical-scale and dial-indicating scleroscopes. How they are calibrated. *Shore Instrument*

1289. Hardness Tester
Bulletin TT-59 on tester for measuring standard Rockwell and superficial hardness. *Wilson Mechanical Instrument*

1290. Hardness Testers
44-page Catalog RT58 on standard Rockwell testers, superficial hardness testers and Tukon microhardness testers. How Rockwell scales are determined. *Wilson Mechanical Instrument*

1291. Hardness Testing
Bulletin A-18 on Alpha Co. Brinell hardness testing machines. *Gries Ind.*

1292. Heat Treat Pots
Catalog on pressed steel pots for lead, salt, cyanide, oil tempering and metal melting. *Eclipse Industrial Combustion*

1293. Heat Treating
Data sheets on Aeroheat 300 and Aeroheat 1000 heat treating salts. Properties, uses, operating characteristics. *American Cyanamid*

1294. Heat Treating
20-page catalog on the Homocarb method with Microcarb atmosphere control for heat treatment of steel. *Leeds & Northrup*

1295. Heat Treating
Monthly bulletin on used heat treating and plating equipment available for immediate delivery. *Metal Treating Equipment Exchange*

1296. Heat Treating
12-page bulletin on heat treating equipment. Applications and special features of 19 different types of furnaces including shaker hearth, conveyor, high-vacuum, elevator-type brazing. *Pacific Scientific*

1297. Heat Treating
Bulletin 14-T on ovens for heat treatment of aluminum and other low-temperature processing. *Young Bros.*

1298. Heat Treating
New 22-page booklet on equipment for heat treating metal in atmospheres. Descriptive diagrams and charts. *Lindberg Engineering*

1299. Heat Treating
24-page Catalog 54 on light-weight

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gives you up to 200 mg/sq.ft. of zinc phosphate coating in 2 short minutes at 95° F.

The Turcoat low temperature phosphating process provides permanent paint adhesion when used at an economical, easy-to-maintain temperature of 95°F. This temperature is *lower* than that required by other "cold" phosphating processes. It is up to 75° *lower* than temperatures required by conventional phosphating processes. You save up to 75% in steam, water, electricity and down-time costs alone!

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Turco has waited to announce low temperature phosphating until it was thoroughly perfected and proven, through exhaustive field testing, to be the very best. For this reason, you'll find that with this new process, just as with Turco's hundreds of other cleaning and chemical processes, you are assured of trouble-free operation, ease of control, and dedicated technical service...anytime, anywhere! Write today for the full story of Turcoat low temperature phosphating, along with Turco's phosphating reference chart. There's no cost ... no obligation.

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processing and heat treating equipment. *Pressed Steel Co.*

1300. Heat Treating Ammonia
24-page "Guide for Use of Anhydrous Ammonia" describes heat treating and other metallurgical uses. *Nitrogen Div.*

1301. Heat Treating Belts
New 16-page booklet on selection of steel processing conveyor belts gives complete specifications. *Wickwire Spencer Steel Div.*

1302. Heat Treating Fixtures
32-page Catalog G-10A lists process equipment, heavy welded fabrications, muffles, trays, fixtures for furnaces, heat treating equipment, pickling equipment. *Rolock*

1303. Heat Treating Fixtures
16-page Catalog M-7 on heat treating baskets and corrosion-resistant-alloy fabrications. *Wiretex Mfg. Co.*

1304. Heat Treating Furnaces
32-page catalog on high-speed gas furnaces for heat treating carbon and alloy steels; also pot furnaces for salt and lead hardening. *Charles A. Hones*

1305. Heat Treating Pots
Bulletin 110 gives data on sizes and shapes of cast nickel-chromium solution pots. *Fahralloy*

1306. Heat Treatment
Bulletin 200 on car hearth, rotary hearth, pit, roller hearth, belt, chain, pusher, and "hi-head" furnaces. *R-S Furnace*

1307. Heating
Bulletin on Heat-O-Coil resistance wire for preheating and stress relieving. *Arcos*

1308. High-Alloy Castings
16-page bulletin, No. 3354-G, gives engineering data concerning castings used for resisting high temperatures, corrosion and abrasion. *Duraloy Co.*

1309. High-Strength Steel
New 14-page booklet on 300-M ultra-high-strength steel. Charts, tables. *International Nickel Co.*

1310. High-Strength Steel
48-page book on T-1 steel, its properties and applications. *U. S. Steel*

1311. Humidity Instruments
New 22-page bulletin on indicating, recording and controlling wet and dry bulb instruments and psychrometers. *Bristol*

1312. Impact Testing
Bulletin on machine for Izod, Charpy and tension testing. *Riehle*

1313. Induction Heating
Folder 15C8053C gives advantages of induction heating and specifications and dimensions of induction heater. *Allis-Chalmers*

1314. Induction Heating
Brochure on low-frequency induction heating. Advantages and applications. *Electric Arc, Inc.*

1315. Induction Heating
36-page bulletin on high-frequency induction heating unit for brazing, hardening, soldering, annealing, melting and bombarding. *Lepel*

1316. Induction Heating
12-page Bulletin HF-58-6 on high frequency induction heating equipment. Heat treating, annealing, brazing, forging, shrink fitting data. *Magnethermic*

1317. Induction Heating
8-page bulletin on high-frequency motor-generator sets for induction heating. *Ohio Crankshaft*

1318. Industrial Furnaces
Folder on batch, automatic, continuous

gas, electric and oil furnaces. Selection chart shows which operations may be performed in which type of furnace. *Sunbeam Equipment Corp.*

1319. Inspection
16-page booklet on magnetic particle inspection. Equipment, uses, kinds of defects that can be found. *Magnaflux*

1320. Inspection
Data on ultrasonic inspection and thickness measurement service in field or laboratory. *Sperry Products*

1321. Instruments
New Bulletin D on thermowells. Types and alloys in which they are available. Specifications in chart form. *Thermo Electric*

1322. Investment Casting
"Pointing the Way" presents 7 case histories on advantages of investment castings. *Engineered Precision Casting Co.*

1323. Iron-Nickel Alloys
A Directory of the U. S. Producers of The Iron-Nickel Alloys includes index of trade names and manufacturers of trade-named alloys. *International Nickel Co.*

1324. Lab Test Dies
Complete information on multi-motion laboratory test specimen dies. *Haller*

1325. Laboratory Equipment
Folder on 5 types of laboratory mixers. Specifications for each type. *Mixing Equipment*

1326. Laboratory Equipment
Bulletin on cutting test specimens describes methods for different types of metals. Price list. *Sieburg Industries*

1327. Laboratory Furnace
Bulletin RT-10 on 25 lb. per hr. laboratory metal treating unit for carburizing, hardening, carbonitriding, brazing, carbon restoration. *Ipsen*

1328. Laboratory Furnaces
Bulletin 1016 on single and dual tube furnaces for combustion analysis. *Sentry*

1329. Laboratory Mill
4-page reprint on rolling mill for laboratory studies, which may be operated as a 2-high, 3-high or 4-high mill. *Fenn Mfg.*

1330. Leaded Steel
New 40-page data book on leaded steel forgings includes test results and case histories. 10 pages of tabular data and 13 of charts. *Alco Products, Inc.*

1331. Lubrication
Bulletin 54 on lubrication of roller and silent chain drives. Oil selection charts. *Sun Oil Co.*

1332. Machining Copper
32-page booklet gives cutting speeds, feeds, rakes, clearances for more than 40 copper alloys. *American Brass*

1333. Magnesium Alloys
New 26-page brochure on properties of magnesium castings, sheet and extrusions for use in the aircraft industry. *Dow Chemical Co.*

1334. Magnetic Alloys
Bulletins 52-100 and 52-151 on applications, characteristics and annealing of Hipernik, Hipernom, Hiperco and Conpernik. Hipernik castings produced by precision casting. *Materials Mfg. Dept., Westinghouse*

1335. Magnetic Materials
64-page book on electronic, magnetic and electrical alloys. Engineering properties and fabrication characteristics. *Carpenter Steel Co.*

1336. Marking
Data on Paintstik markers for identification of heat treated parts. *Markal Co.*

1337. Marking Machines
Bulletins 146-C25 and 146-C26 on complete line of marking machines, from stationary models to portable units. For polished surfaces, precision finished parts, glass, ceramics. *Jas. H. Matthews*

1338. Melting Furnaces
32-page catalog on Heroult electric furnaces. Design, types, sizes, capacities, ratings. *American Bridge*

1339. Metal Cutting
56-page Catalog No. 32 gives prices and describes complete line of rotary files, burs, metalworking saws and other products. *Martindale Electric*

1340. Microhardness
Data on microhardness tester with readings corresponding to Vickers. *Newage Industries*

1341. Microhardness Tester
Bulletin describes the Kentron microhardness tester. *Torsion Balance*

1342. Microscopes
Bulletin on four dynoptic metallurgical microscopes. Features, accessories, light sources. *Bausch & Lomb*

1343. Microscopes
Catalog on metallograph and several models of microscopes. *United Scientific*

1344. Nondestructive Inspection
New 12-page booklet on use of X-rays and gamma rays in industry. Advantages and disadvantages of each type of radiation. *Picker X-Ray*

1345. Nondestructive Testing
8-page bulletin on equipment for non-

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(Continued from page 47)

destructive testing of bars, rods, tubing. *Magnetic Analysis*

1346. Nonferrous Alloys
New alloy chart showing comparative specifications, chemical analyses and the minimum physical properties of centrifugally cast nonferrous alloys. *Centrifugally Cast Products Div., Shenango Furnace*

1347. Nonferrous Wire
Folder gives wire gage and footage chart and data on beryllium copper, phosphor bronze, nickel, silver, brass and aluminum wire. *Little Falls Alloys*

1348. Oil Quenching
8-page brochure tells in detail how carbon steel often can replace alloy steel when additive is used in the quenching oil. *Aldridge Industrial Oils*

1349. Ovens
Bulletin 4-257 on gas, oil and electric ovens. Load-carrying-door, electric-drawer and walk-in type ovens. *Grieve-Hendry*

1350. Phosphate Coating
Bulletin gives advantages of phosphate coating, how to apply coating and a selection chart for the various grades. *Amchem Products*

1351. Phosphating
Bulletin on Ty-Bond series of cleaners and zinc and iron phosphate compounds. *Cowles Chemical*

1352. Phosphating
Free phosphating analysis kit to determine if products are adaptable to phosphating. *Turco Products*

1353. Phosphor Bronze
Facilities for rolling, cleaning, welding, trimming and treating phosphor bronze. *Rolling Mill Div., Miller Co.*

1354. Plating
Data and specification sheet covering tin plating a wide range of nonferrous thin strip metals. *Somers Brass Co.*

1355. Potentiometers
4-page Bulletin 1271 on small self-balancing electronic potentiometers and bridges. *Bristol Co.*

1356. Powder Metallurgy
Technical literature on high-density sintered metal parts. *Supermet Div., Globe Industries*

1357. Powdered Iron
Properties of Plast/Iron with and without copper. *Plastic Metals Div.*

1358. Powdered Metals
24-page catalog 815 on 37 different models of powder metal presses. *Stokes*

1359. Pyrometer
12-page Bulletin No. 4257 on contact pyrometer for surface temperatures, describes and illustrates instrument and its uses. *Illinois Testing Lab.*

1360. Pyrometer
New bulletin on Shawmeter, direct-reading two-color pyrometer. *Shaw Instrument Corp.*

1361. Quenching
16-page booklet on modified and full marquenching procedures. Hardness and dimensional control data, cooling curves, case histories. *Sinclair Refining Co.*

1362. Radiation Products
8-page catalog on equipment for nuclear research. Radioactive sources, shielding and exposure equipment, instruments, services. *Budd Co.*

1363. Radiography
Article on radiographic inspection of spot welds of light metals in Resistance Welding at Work, Vol. 5, No. 4. *Sciaky Bros.*

1364. Rare Earth
Bulletin on rare earths and yttrium metals. *Lindsay Chemical Div.*

1365. Recorders
Bulletin F-8938 on series 2000 and 3000 potentiometer recorders. Specifications. *Wheelco Instruments Div.*

1366. Refractories
24-page manual on mortar preparation and general instructions. Bibliography. *Lumnite Div.*

1367. Refractory Coating
Data on aluminum oxide and silicon carbide coating which may be sprayed on. *Norton Co.*

1368. Refractory Metals
Booklet on tungsten, molybdenum, tantalum, their properties and uses. *Fansteel Metallurgical*

1369. Resistance Alloy
8-page catalog of copper-nickel resistance wire. Physical properties, specifications, resistance for 54 wire sizes and 31 ribbon sizes. *Hoskins Mfg.*

1370. Rust Prevention
New 20-page booklet on causes of rust and application of preventives. Data on rust preventing liquids and recommended applications. *Rust-Lick, Inc.*

1371. Rust Removal
Folder on new alkaline cleaning material for removal of rust, certain types of heat scale and metallic smuts. *Oakite*

1372. Salt Baths
New 76-page Catalog 117 on salt bath equipment and procedures describes ceramic tile pot furnaces with removable submerged electrodes. Technical data, applications. *Ajax Magnethermic*

1373. Sand Systems
Bulletin No. SL-3 shows layout of system and controls. *Harry W. Dietert*

1374. Shot and Grit
14-page catalog describes cast steel, malleable iron, chilled iron, cut wire and other forms of abrasive shot and grit. Methods of shot peening and impact cleaning. *Abrasive Shot & Grit*

1375. Shotblasting
16-page "Primer on the Use of Shot and Grit". Problems of blast cleaning operations. *National Metal Abrasive*

1376. Silicon Carbide
8-page booklet on silicon carbide refractory. High-temperature properties. Shapes. Design practices. *Refractories Div., Carborundum Co.*

1377. Sintered Carbides
24-page booklet on the characteristics of the various grades, for research and design engineers. *Kennametal*

1378. Smelting
New 16-page brochure on electric-furnace smelting and refining of iron ore. Plant layout. Power and electrode requirements. *Koppers Co.*

1379. Soldering Fluxes
4-page bulletin on line of nonacid self-cleaning fluxes. How they work. *Lake Chemical Co.*

1380. Special Alloys
8-page bulletin gives products and facilities for producing titanium wire, zirconium wire, special alloys, vacuum melting. *Johnston & Funk Metallurgical*

1381. Specimen Grinding
Metal Digest, Vol. 5, No. 1, describes fine grinders for metallographic specimens. Accessories and supplies. *Buehler*

1382. Spectrographs
Newsletter, January 1959, describes new vacuum spectrographs. Models available. *Jarrell-Ash*

1383. Spring Steel
New 43-page stock list of cold rolled spring steels. Standard stock sizes. Weight tables for computing weight from thickness. Metric, gage and hardness conversion tables. *Uddenholm Co.*

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48-page booklet on selection of spring steel. How it is made, hardness values, physical property data. *Wallace Barnes Steel Div., Associated Spring*

1385. Stainless Steel
12-page booklet on new AM 350 chromium-nickel-molybdenum stainless steel which is hardenable by subzero cooling or double aging. *Allegheny Ludlum*

1386. Stainless Steel
New data sheets covering 17 types of stainless steels. Chemical composition, applications, processing, physical and mechanical properties, machining, forming, welding. *Jones & Laughlin*

1387. Stainless Steel
New 36-page book on commercial grades of sheet and strip. Corrosion resistance of stainless Types 302, 316, 430 and aluminum Type 1100. Properties and analyses, finishes. *Washington Steel*

1388. Stainless Strip
32-page brochure on 20 types of stainless strip steel. Recommended applications, chemical, mechanical properties, corrosion resistance. *Superior Steel*

1389. Steel
Chart gives properties, analyses specification designations and heat treatment of carbon, alloy and stainless steel castings. *Lebanon Steel Foundry*

1390. Steel
Bulletin on Yoloy "S" steel. Properties, welding, chemical analysis, corrosion resistance, strength. *Youngstown Sheet & Tube*

1391. Steel Tubing
Catalog on seamless and electric-resistance welded steel tubing. Sizes, shapes, compositions. *Ohio Seamless Tube*

1392. Steelmaking
24-page booklet on melting, forging, heat treating, machining and other facilities. Type of products produced. *Midvale-Heppenstall Co.*

1393. Steelmaking Additive
Data on additive which cleans melts without changing analysis. *WaiMet Alloys*

1394. Strain Gages
New folder on SR-4 etched foil gages gives characteristics and specifications. *Electronics & Instrumentation Div., B-L-H*

1395. Strip Mill
Data on cold reduction mill. *Loma Machine Mfg. Co.*

1396. Testing
Brochures on facilities for metallurgical testing. Methods of analysis of high-temperature alloys. *Frank L. Crobaugh*

1397. Testing
Literature on pickle pills for testing strength of pickling solutions. *Ferro Corp.*

1398. Testing Machines
12-page catalog on ten testers including hardness, ductility, tensile, compression and transverse strength. *Detroit Testing Machine*

1399. Thermocouple Insulators
Bulletin No. 300-56 on complete line of thermocouple insulators. Dimensions, sizes, types of insulators. *Claud S. Gordon*

1400. Thermocouples
18-page Catalog P58 on thermocouples and their components. Sizes, prices, specifications. *Pyrometer Co. of America*

1401. Thermocouples
32-page file book on pyrometer accessories. Selection of thermocouple and protective tube. *West Instrument*

1402. Thickness Tester
Bulletin 400 on electronic testers for determining plating thickness. Applications of various models. *Kocour Co.*

1403. Titanium
Folder on commercially pure, unalloyed titanium gives properties, types supplied, forming methods, cleaning. *Mallory-Sharon Metals*

1404. Titanium
New bulletin on titanium production and use. Mechanical properties. *Republic Steel Corp.*

1405. Tool Steel
Color guide to estimate temperatures has heat colors on one side and temper colors on the other. *Bethlehem Steel*

1406. Tool Steel
4-page bulletin on Ry-alloy, oil-hardening tool steel. Applications, advantages, heat treatment, forging. *Ryerson*

1407. Tool Steel
New 12-page brochure on low-temperature air-hardening tool and die steel. Fatigue properties, response to heat treatment. *Universal-Cyclops*

1408. Tool Steel
16-page catalog section gives sizes and prices of oil-hardening and air-hardening tool steels and low-carbon stock. *Brown & Sharpe*

1409. Tool Steels
New 40-page bulletin on tool steels for bar and tube extrusion. Heat treatment of hot working steels used in extrusion presses. *Marathon Specialty Steels*

1410. Tubing
Bulletin TB-361 on designing with mechanical tubing. Types, grades, finishes, shapes. *Tubular Products Div., B. & W.*

1411. Tubing
Data Memorandum No. 7 on beryllium-copper tubing. Mechanical and physical properties. Application, corrosion resistance, heat treatment and fabrication. *Superior Tube*

1412. Tubing
16-page design and data booklet on metal gathering and flotrusion processes for producing tubular parts. *Tapco Group, Thompson-Ramo-Wooldridge*

1413. Tungsten
20-page bulletin on manufacture, properties and uses of tungsten. Flow chart of tungsten production. *Sylvania Electric Products*

1414. Ultrasonic Cleaning
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New bulletin on vacuum melting furnaces which can be used in production or laboratory. *Zak Machine Works*

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6-page folder on industrial X-ray films and processing chemicals. Exposure characteristics. Selection of best film for each job. *Ansco*

1422. Zinc Coating
8-page booklet on zinc-coated steel sheets. Fabrication, uses, advantages in heating, ventilating and air conditioning. *Weirton Steel*

JUNE, 1959

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1193	1218	1243	1268	1293	1318	1343	1368	1393	1418
1194	1219	1244	1269	1294	1319	1344	1369	1394	1419
1195	1220	1245	1270	1295	1320	1345	1370	1395	1420
1196	1221	1246	1271	1296	1321	1346	1371	1396	1421
1197	1222	1247	1272	1297	1322	1347	1372	1397	1422
1198	1223	1248	1273	1298	1323	1348	1373	1398	
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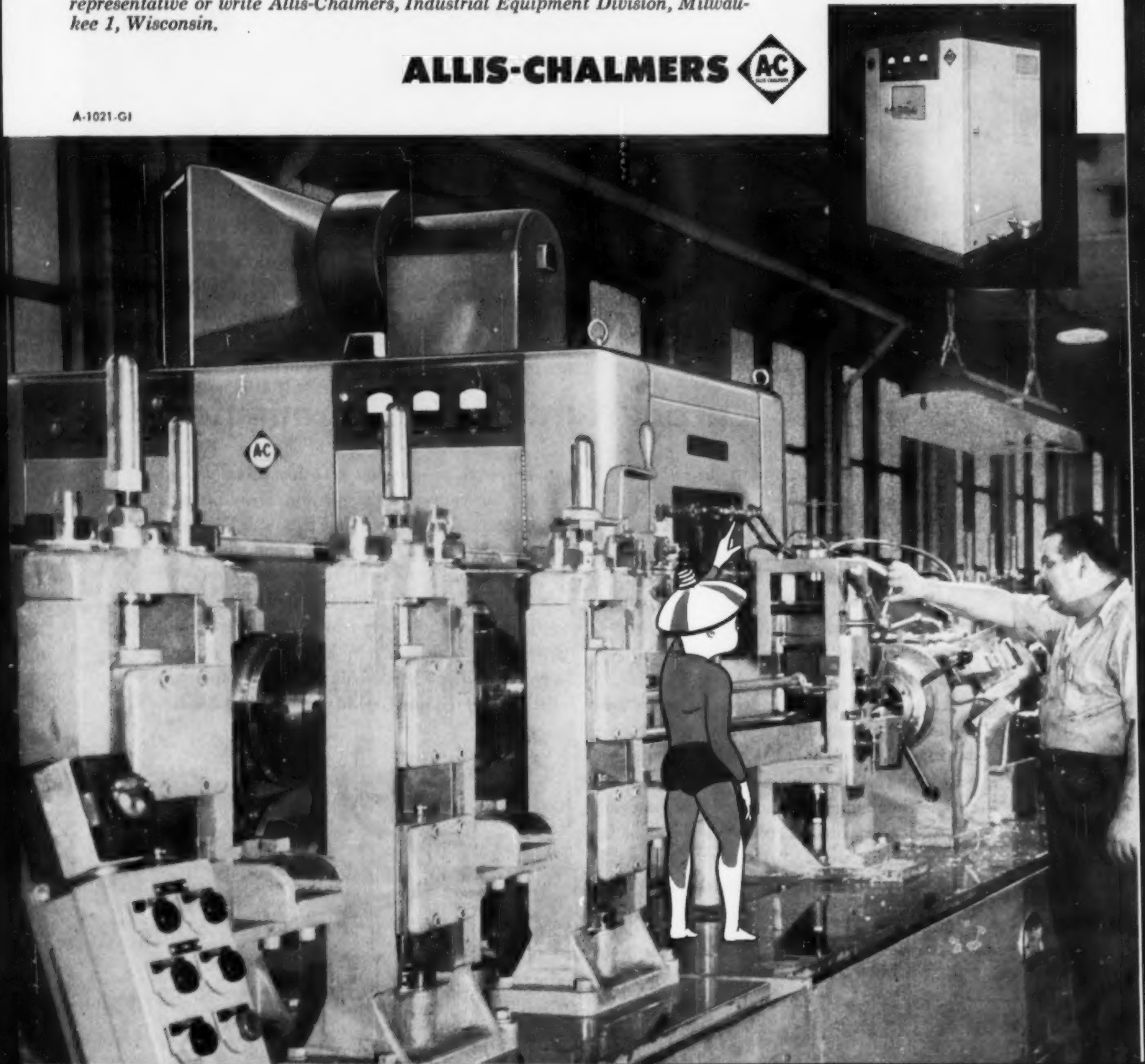

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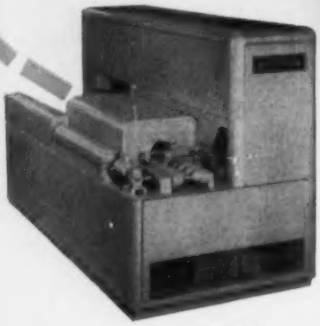

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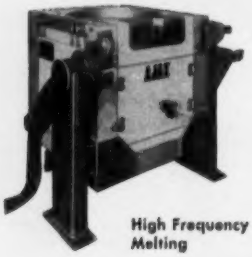

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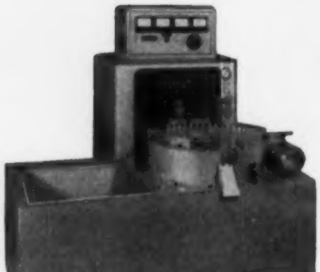

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HAWK Guided Missile Creates Unusual Tool Steel Problem

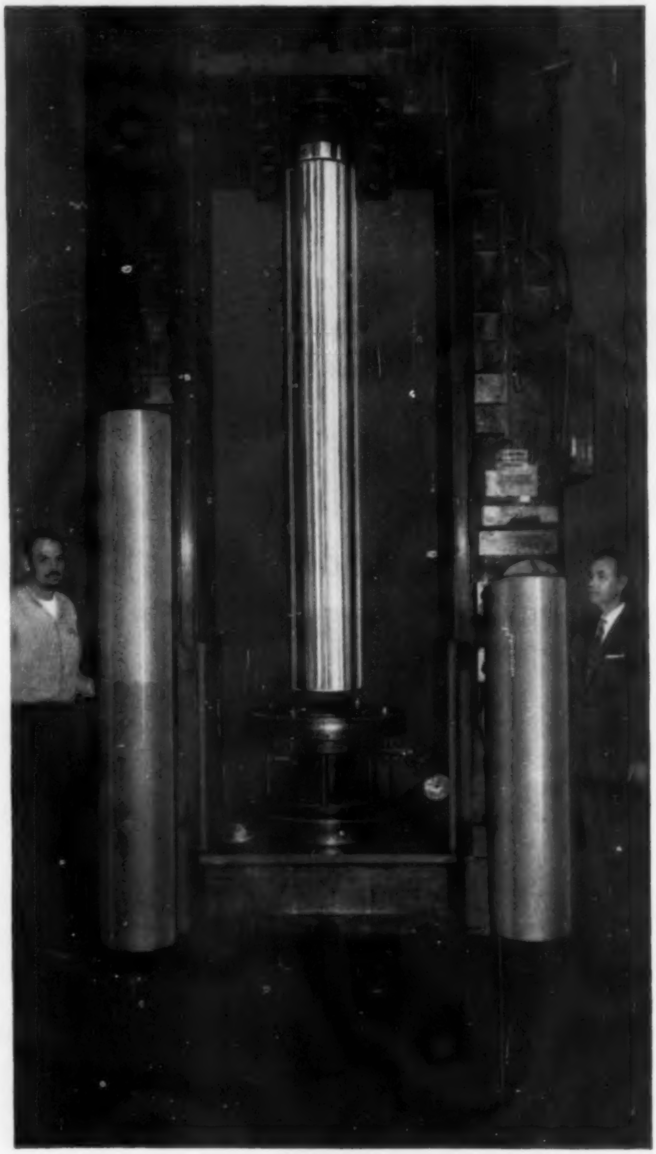
Uddeholm HOLLOW TOOL STEEL Provides Quick, Economical Answer

To produce motor cases for the Hawk Guided Missile, Norris-Thermador Corp. of Los Angeles, Cal., needed quick delivery of an unusual piece of non-deforming, hollow tool steel. The answer to their needs turned up no farther away than Uddeholm's Los Angeles warehouse.

The Hawk's motor tube required a finished length of 83⅜" and an outside diameter of 14 inches. It was deep-drawn as an integral cylinder from a 42⅝" circular blank. The operation consisted of cupping, reduction, combination reduction and iron, and two other ironing operations—plus the usual annealing and lubricating cycles.

For the final iron punch, Uddeholm supplied Norris-Thermador with a piece of UHB-46 (SAE 01) Oil Hardening Hollow Tool Steel 14" o.d. x 7" i.d. over 8 feet long *directly from warehouse stock*. Little metal removing was required to produce finished diameters of 7.250" on the inside and 13.920" on the outside—pointing up the labor and scrap-saving features of hollow tool steel. Equally important, heat treating of this long piece in a vertical "drop bottom" furnace produced virtually no distortion.

The excellent non-deformity and close stock size of the Uddeholm steel were exactly right for this job. This is typical of Uddeholm's ability to provide quick delivery of the right tool steel in the right size for every job. For quick service or just helpful information, keep in touch with your Uddeholm tool steel representative.



Hydraulic press with final iron punch of UHB-46 Hollow Tool Steel. Finished, "as-drawn" tube shown at left.

Write For Tool Steel Stock List No. 13

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Memo on Metals

Crucible Alloy Offers High Impact Strength, Hardness at 220-240,000 psi Strength Levels

Today's ultra-strength steels possess a unique combination of mechanical properties even when they are used at their ultimate levels of tensile strength. One of the first steels developed in this class — Crucible HY-Tuf® — combines high impact strength, hardness and good ductility at the 220,000/240,000 psi range.

HY-Tuf (1.8% Ni, 1.30% Mn, 1.50% Si, 0.40% Mo) was first widely used in aircraft applications because of its favorable strength-weight ratio. But, because it is also tough and hard, it has rapidly found its way into power-driven garden tools, hand- and power-operated banding machines, rock bit bodies, cutter head bolts, couplings, pinion gears and shafts.

HY-Tuf's high impact strength, especially at high levels of tensile strength or hardness, has been demonstrated in a great number of tests. These tests prove HY-Tuf definitely superior to standard AISI alloy steels in impact strength and ductility at hardnesses above 42 Rc or tensile strengths above 190,000 psi. For specific comparisons, see Figures A and B.

FIG. A—TENSILE AND IMPACT DATA

Grade	Temper	Rc	Tensile Strength, psi	.2% Yield Strength, psi	.01% Yield Strength, psi	% Elong. in 2 in.	% of Red. Area	Izod Impact Ft-Lb
HY-Tuf	550F	46.5	234,000	193,000	154,000	13.1	49.7	31
4340	700	46	228,000	212,000	210,000	11.2	47.8	17
4140	800	46	227,000	205,000	198,000	11.2	39.4	8
9442	700	46	225,000	203,000	200,000	10.3	43.4	11

Oversize .505" dia. tensile specimens and finish machined Izod specimens were oil quenched from the conventional austenitizing temperatures and tempered as indicated.

FIG. B—MAXIMUM IMPACT PROPERTIES
(at hardness of Rockwell C45 or greater)

Grade	Izod			Tension Impact			
	Ft-Lb	Temper	Rc	Ft-Lb	Elong.	Temper	Rc
HY-Tuf	33	400F	47.5	195	16	None	47.5
4340	13	860	45	158	12.2	400F	55
4140	17	500	52	160	14	375	55
8630	19	400	51	148	14	200	52.5
4130 (oil)	17	500	47.5	133	14.5	200	50
4130 (water)	21	450	50	142	13.0	200	52.5

The alloy's superior ductility is shown by these slow bend tests performed on ⅞" rod bars heat treated to 47 Rc.

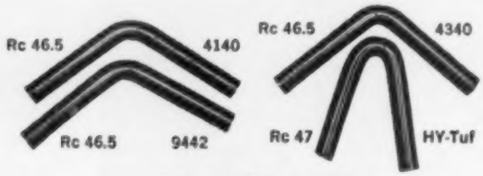
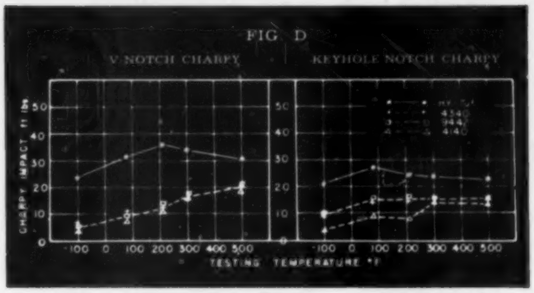


FIG. C—BEND TESTS
Bars — ⅞" rd.

HY-Tuf's notch sensitivity is much lower than that of conventional steels at hardnesses of 45 to 47.5 Rc. Unlike other alloys, HY-Tuf has higher impact values for the V-notch Izod test than for the keyhole Charpy test. This is important because it means that HY-Tuf is much less sensitive to a notch at high strength levels than ordinary steels.

Crucible HY-Tuf conforms to MIL-S-7108 and AMS 6418 and is available in commercial sizes and quantities. For more information on this ultra-strength alloy, send the coupon.

** ultra-strength steel's impact strength, hardness*
** titanium price reductions*
** permanent magnet handbook*



Effect of testing temperature on the notch impact values of HY-Tuf and conventional steels heat treated to 47 Rc.

New Low Prices of Titanium Mill Products Justify Using The Alloy in More Applications

Early this year Crucible's Titanium Division announced new price reductions for its titanium mill products — that cut these prices to *a new industry low.* The reductions, as much as 25%, affected both base prices and the costs of "extras".

For example, sheet was cut from $9.10 per pound base price to $7.50. Strip was reduced $1.25 per pound to $7.25. Plate, formerly $6 per pound, now costs only $5. Crucible also slashed billet prices to $3.55 per pound and wire to $5.50 per pound. Bar items were reduced $1.00 per pound to $4.25 (base price). In addition, some size "extras" were reduced as much as 55%, and finished "extras" by over 40%.

Because of these lower prices, engineers can now utilize titanium's unique properties in many more applications and justify the selection economically. (Even at previous prices, titanium often proved itself the low-cost metal on a cost-per-service-year basis.) This should prove especially true in processing applications requiring corrosion resistance and long-service life, and in aircraft and missile applications where high-strength, lightweight materials are essential.

During the past five years, titanium fabricating costs have also been cut substantially because of experience gained in forging, machining, welding and forming. *For detailed information on Crucible titanium mill products, send the coupon.*

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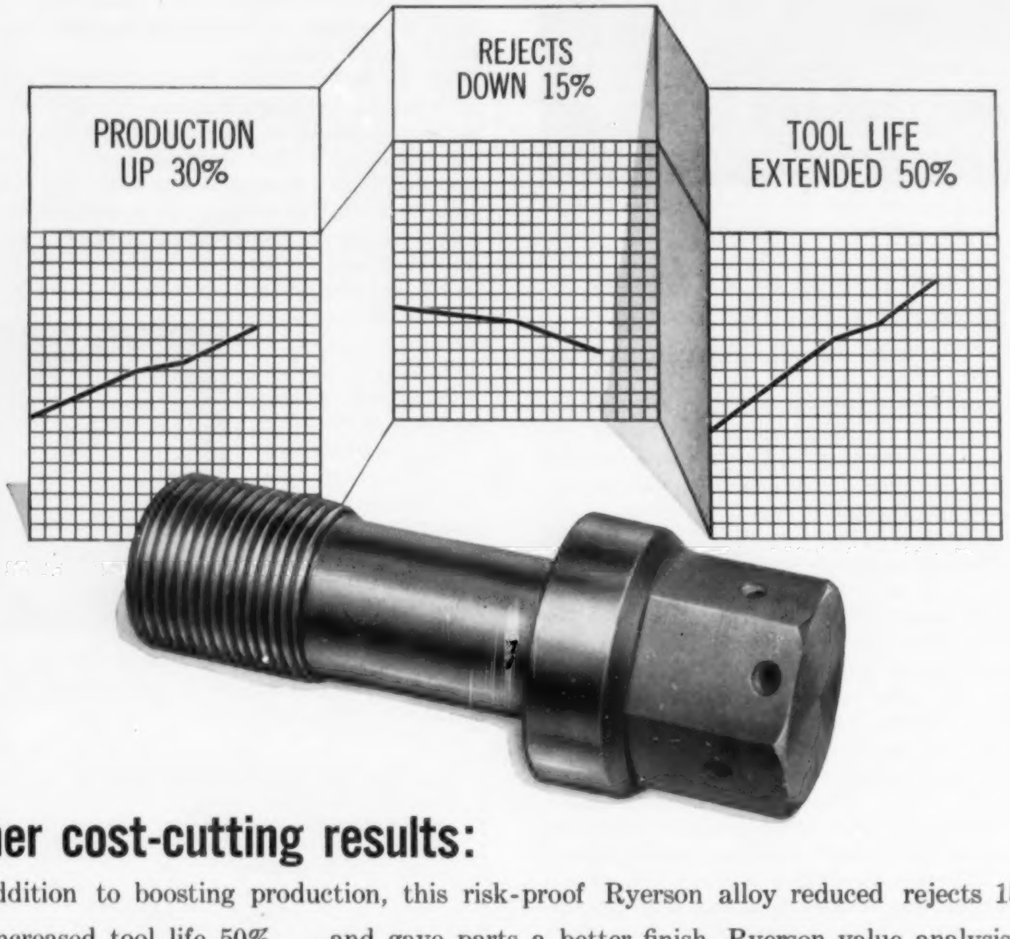

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Metal Progress
Vol. 75, No. 6 June 1959

Critical Points

By the EDITORS

Inventions Wanted!

METAL ENGINEERS, are you bored with solving the same old problems day after day? If so, you will be interested to know that the United States military leaders also have a neat list of perplexing difficulties, and they are anxious to find the answers. We discovered this by reading a little brochure entitled "Inventions Wanted by the Armed Forces". Published by the Department of Commerce, the booklet describes 134 items needed by the various services. Chemical and electrical engineers have a greater number of problems (34 and 31, respectively) to sink their teeth into, but metallurgists can while away spare time in finding the solution to an even dozen tough ones. So, if you want to give the defense effort a shove forward (and acquire a few extra dollars), pay attention to the following:

Among other things, the services think that a material which would retain magnetism above 1850° F. would be useful. Too easy? How about devising a reliable, low-cost sandwich bond? If you think that a gooier mustard or mayonnaise ought to do the trick, you are advised not to write in; the services are referring to the attachment of sheet to honeycomb core in aircraft construction. They would also like a corrosion and wear resistant coating for magnesium. They will take it with or without good electrical conductivity; they aren't fussy.

A tough metal coating is wanted for cannon bores. It should be better than electroplated chromium in erosion and wear resistance, with improved ductility, and adhesion to base metal. At the same time, it should retain the hardness of electroplated chromium (Knoop 960). This new coating does not necessarily have to be electrodeposited, if that is any help.

One item that seems to be causing the services trouble is the base material for "arresting hook points – a material which is ductile to prevent shattering under impact, of high hardness and strength, and one which will not lose appreciable strength at elevated working temperatures (1000° F. from jet exhausts) and will readily take coatings". For those who wonder just what an "arresting hook point" is, it refers to the hook

which slows down a jet plane during its landing on an aircraft carrier.

After you have solved these and the other problems in the "Metallurgy and Metal Fabrication" section, you can give the other engineers a hand. For instance, you might develop the "lightweight, simple electric shock system for cleaning metal" that electrical engineers are requested to devise. It is needed to substitute for sand-blasting, chemical and other processes to remove paint. Metallurgists can also help mechanical engineers in working out excavating equipment for Arctic areas. Capable of boring or digging large holes in frozen ground, the machine should also be of limited weight and size to permit air transport and mobility over frozen terrain, once on the ground. Endurance and long life aren't essential in this equipment, which simplifies this problem slightly.

These are only a few examples from this interesting little booklet; solving all 134 should keep engineers busy for years.

Golden Anniversary

In the spring of 1909 two dozen foremen platers got together to pool their information on electroplating, metal finishing and allied arts. Out of their planning, the National Electro-Platers' Association of the United States and Canada (N.E.P.A.) came into being, reorganized in 1913 as today's American Electroplaters' Society (A.E.S.). From these beginnings, the Society has grown into a world-wide technical organization with 58 autonomous branches and some 8000 individuals who pride themselves in their membership. Individually and as a group they have fostered the development of metal finishing along scientific lines, so important to industry today.

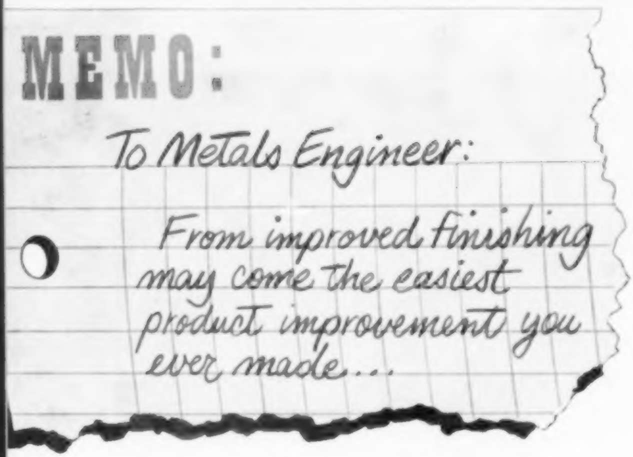
Plating and finishing have come a long way in the 50 years that the American Electroplaters' Society has been in existence. In many plants turning out metal goods, processes required to give desired surface appearance and needed corrosion resistance represent one third to one fourth of the total activities. This is because durability and appearance are among the most important attributes of any product. Today, finish is a potent factor in sales appeal. More than a billion dollars is invested in plating and finishing equipment and the value added to a product by finishing processes may vary from a fraction of its cost to more than 50%.

Plants now use large tanks of plating solutions, precisely controlled, compared to the small vats of the past which were maintained largely by trial-and-error because of the operator's limited knowledge of the scientific principles. Other finishing has developed significantly, too; operations are mechanized and precisely controlled. Even so, there's still a definite trend toward putting more science into the art of finishing. More and more, the selection of materials for a product is being considered in light of the type of finish desired. Whether in the laboratory or plant, progress in finishing will demand the most advanced principles of engineering, metallurgy, chemistry and physics.

The occasion of the 50th anniversary celebration this month, at A.E.S.'s Golden Jubilee Convention and Industrial Finishing Exposition in Detroit, is a fitting time to reflect on the motto of the original National Electro-Platers' Association – a maxim by Amiel so cherished that it prefaced the preamble of the N.E.P.A.'s constitution and bylaws:

> "I shall pass through this world but once.
> Any good thing, therefore, that I can
> do, or any kindness that I can show to
> any human being, let me do it now.
> Let me neither defer nor neglect it,
> for I shall not pass this way again."

The growth and many contributions made by A.E.S. is indisputable evidence that the precepts of its founders have been followed. May the future be even brighter!



No. 1 in a Series on Better Finishing

More colors to choose from . . . Better chemical and heat resistance . . . One-coat finishes . . . Thinner coating and lower firing frits . . . New base metals – aluminum and stainless . . . Improved enameling steel and greater use of cold rolled steel . . . Continuous production lines with automatic spraying and dipping . . . These developments give porcelain enamel finishes greater versatility with lower cost. (L27)

New Possibilities With Porcelain Enamel Finishes

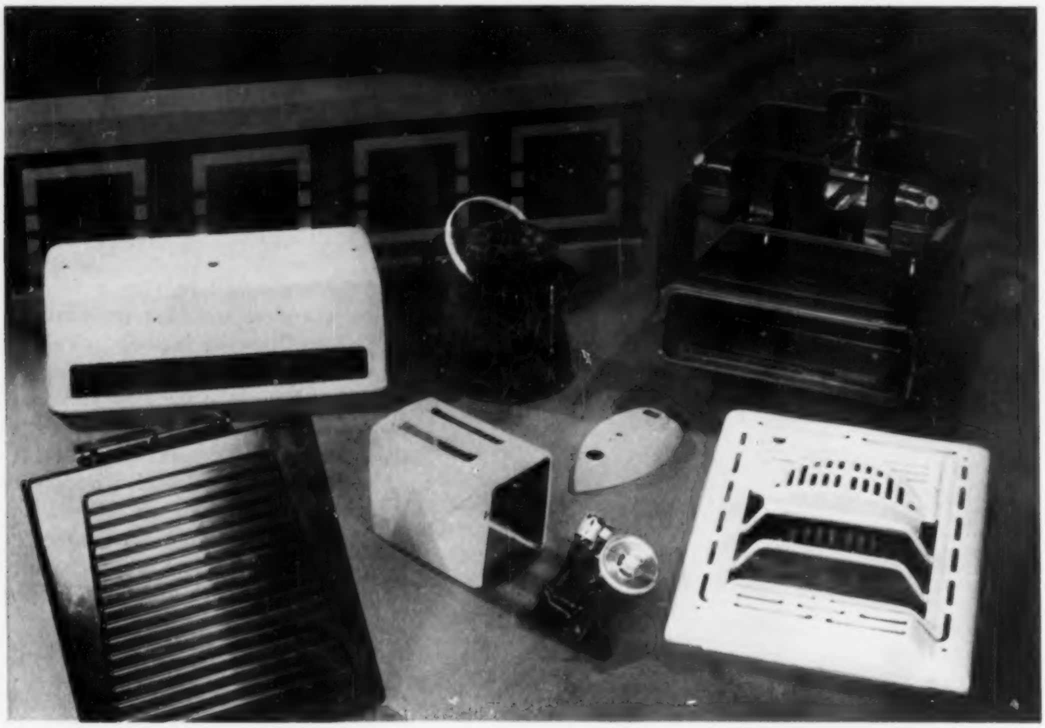
TODAY'S porcelain enamel finishes are different from the familiar white coating on cooking utensils so familiar in years gone by. New colors and textures have been developed. These include titania enamels for a wide variety of household appliances and architectural applications, and satin, semigloss and low-gloss enamels for uses where a high-gloss finish would be undesirable. Improvements go beyond the decorative level. Porcelain enamels are now formulated for acid and alkali resistance, abrasion and impact resistance and to meet a number of other difficult design and engineering problems.

The versatility of modern porcelain finishes has been improved by elimination of ground coats – in other words, one-coat enameling. This process has been brought about by the use of special steels and more recently by the advent of special cleaning and pretreatment methods for sheet iron. This and other developments have made it possible to reduce the over-all thickness of enamel coatings, giving more resistance to impact damage and extending the possibilities for design of parts. The development of frits with lower firing temperatures has also made the design and fabrication of parts to be enameled less critical and has allowed cold rolled steel and aluminum to be used as base metals for many parts.

The editors acknowledge the generous assistance of the Porcelain Enamel Institute. Special credit is due E. E. Bryant, Ferro Corp., for advice in behalf of P.E.I.'s Technical Publications Committee.

Selecting an Enamel

Emphasis should be on determining requirements, then selecting a coating which will provide the needed properties. A large number



of enamel formulations (most of them proprietary) are available for different applications. The best choice is usually made by discussing specific requirements of the finish with producers of enamel frits. However, it's important to know, in general, what's available from the frit industry and the possible variations in finishes which can be achieved. Porcelain enamel is truly unique in the scope of its properties and its adaptability.

Looking at chemical properties, porcelain enamel's resistance to chemical attack (by alcohol, gases, water and other corrosives, for instance) is one of its most useful characteristics. "Acid resisting" frits are available. All grades are immune to organic solvents and resist mild alkalis with a pH of 7 to 10. The hot water storage tank with its "glass lining" is a good example of porcelain enamel usage because of its resistance to chemical deterioration and its sanitary appeal.

In its thermal properties, porcelain enamel is flameproof and resists temperatures as high as 1500° F. It withstands thermal shock due to sudden temperature drops of as much as 800° F. Cold and sudden freezing temperature have no harmful effects. Ceramic coatings, special types of porcelain enamel formulated for temperatures

Fig. 1 – Color Combined With Versatile Engineering Properties Is One Reason Modern Porcelain Enamel Finishes Are Moving Ahead on Industrial and Consumer Products

as high as 2500° F., have been developed to meet individual requirements (see *Metal Progress*, November 1958, p. 111).

Physical Properties – Surface hardness varies from 3½ to 6 on Moh's scale and to a corresponding range of about 149 to 560 in Knoop hardness numbers. The Sward Rocker hardness test, where plate glass equals 100, shows the hardness of porcelain enamel as 100. This glass-like surface is one of the best coatings known for resisting abrasion and wear. This combined with its low coefficient of friction or "slipperiness" makes porcelain particularly adaptable to applications requiring a smooth sliding surface which will not pit, scratch or wear. The glass-like finish is one of the easiest surfaces to clean and colors are permanent. This property gives the finish a high sanitary rating.

Porcelain enamel is also an electrical insulator and a good barrier against electrolytic corrosion. Measurements on electrical resistance give values ranging from 100 to 300 ohms per mil of thickness. Certain enamels also have a dielectric strength up to 1000 v. per mil of thickness. These

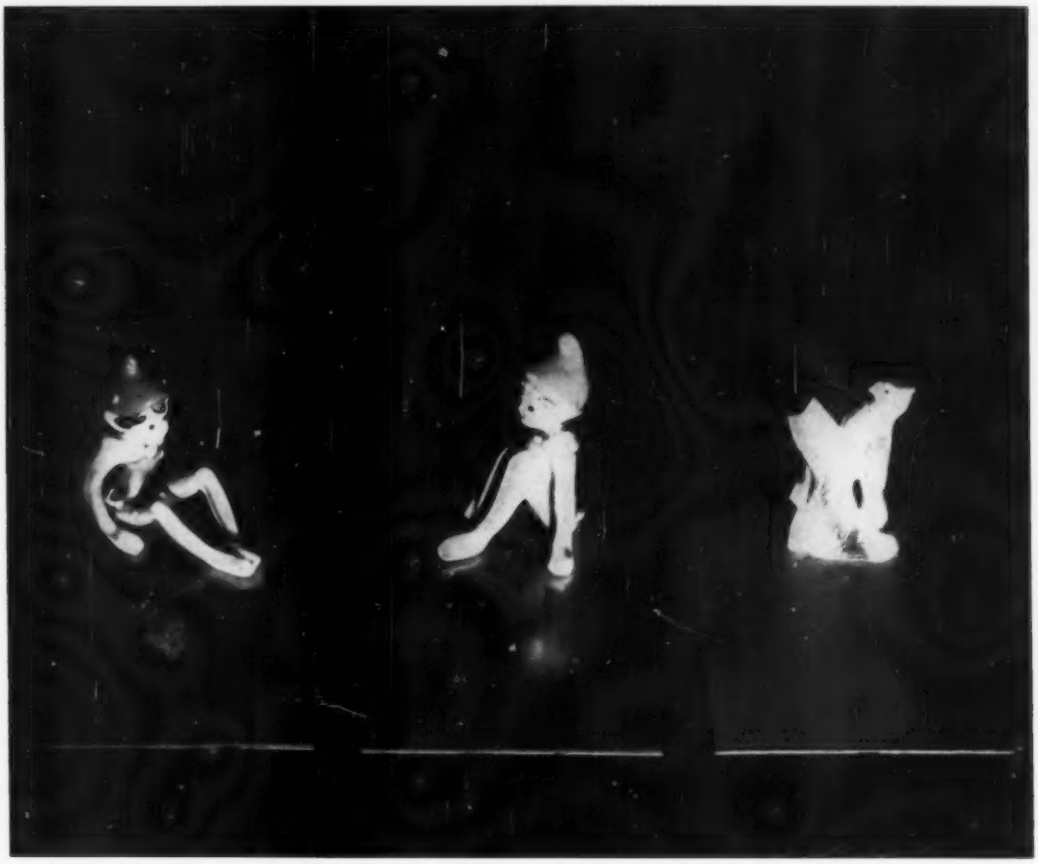


Fig. 2 – Reflections of the Figurines Show the Range of Finish in These Porcelain Enamel Samples Which Are All in the Same Shade of Green. Full gloss (left), semigloss (middle) and full matte (right).

properties decrease with increase in temperature but are still good up to 500° F.

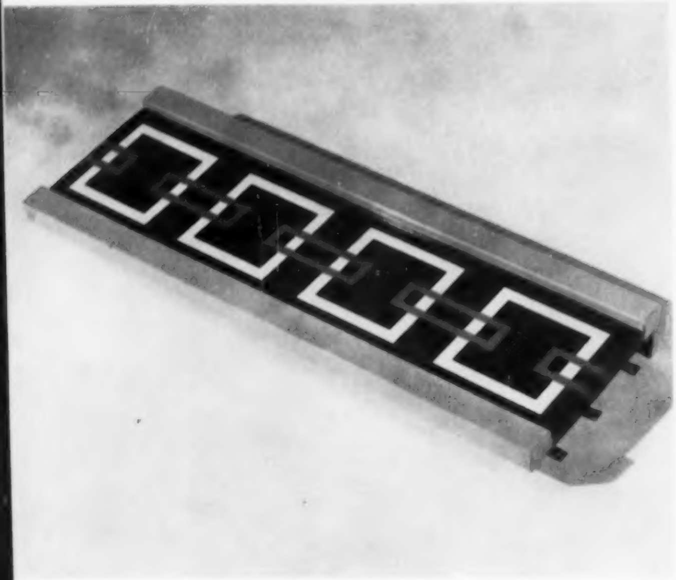
Appearance – Colors which are available in modern frits are almost unlimited. Pastels, dark rich colors and pattern combinations can be obtained in any shade or hue. All colors are nonfading and will not stain or peel because, in porcelain, color is an integral part of the finish. This color permanence has been emphasized by the 15-year weathering tests conducted by the Porcelain Enamel Institute and National Bureau of Standards, results of which were recently made available. Acid resistant enamels show excellent weathering qualities and color retention under severe atmospheric conditions.

Three main classifications of textures are available: glossy, which offers minimum friction, ease of cleaning, highest reflectance and greatest sheen; semigloss or satin finish for many decorative applications; and low-gloss for applications such as chalkboards. Here again, selection should be based on the requirements of the service. For example, a full matte finish, while needed for chalkboard service, is not recommended for architectural and many other applications due to its poor cleanability and its lesser weather resistance.

Porcelain enamel can be applied to corrugated, embossed, Rigidized and other textured metals. Mottled, pebbled and other variegated textured effects also contribute to the variety of design possibilities, either in the same color or in a harmonizing color combination. Some of the many possibilities for increasing sales appeal of products with novel porcelain finishes are given on following pages.

More on Decorative Appeal

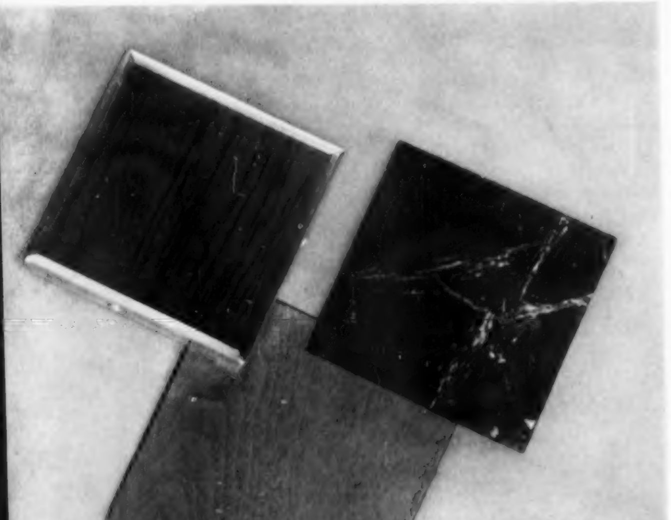
How to Get More Decorative Appeal From Porcelain Enamel



Stenciling and Brushing

Effect – The design is made up of solid areas of color overlying the first finish coat. Color areas are clear-cut, with sharp edges. Texture is smooth and usually glossy, but low-gloss or semigloss enamels may be used. The process is applicable only to flat areas or smoothly curved surfaces. It is well adapted to signs and has possibilities on stoves, appliances and other products.

Production – One coat of finish background color is applied over a ground-coated part. Colored slip is sprayed over the entire area of the design and dried. A stencil (usually of heavy paper) is placed over the piece, accurately positioned, and the unfired enamel not covered by the stencil is brushed off. For intricate designs, two or more stencils may be used in succession. The cost of preparing stencils is low. However, it is usually not possible to produce very fine detail by this process.



Graining or Marbleizing

Effect – Originally "graining" meant a reproduced wood-grain design and "marbleizing" referred to a design of polished marble. The technique can be used to reproduce any over-all design which can be reproduced in two colors, that of the finish coat of porcelain enamel and the pattern of the graining paste. The finish is usually glossy and smooth, but can be produced in a semigloss or matte texture. This is a good method for producing an over-all design on large parts, such as table tops, stove panels and architectural pieces.

Production – Graining or marbleizing is essentially a printing process by which an over-all design is transferred to the ware by means of a roll. The design may be molded into the roll or etched on a steel or copper plate. The graining paste or ink is an intimate mixture of finely ground flux and colorant, suspended in an organic vehicle with a consistency to give a distinct reproduction and not clog the etching. The first cost for the roll and plate is relatively high, but the cost per piece is fairly low.

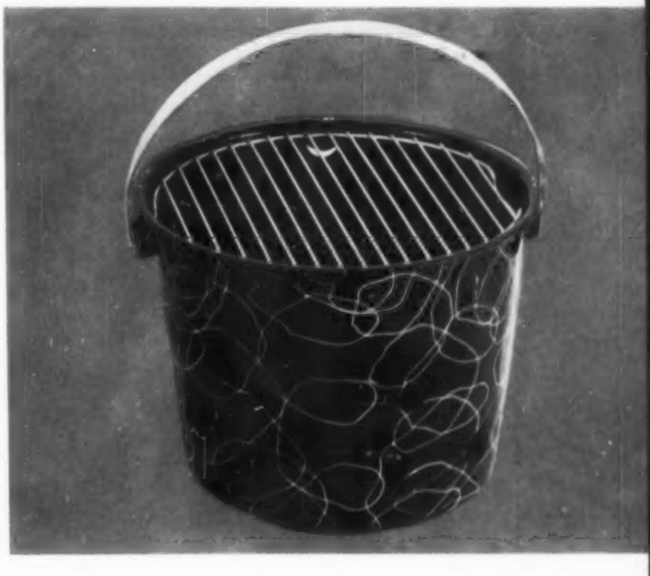
Stippling or Speckling

Effect – The finished surface has a pebbly texture, usually glossy, with spots or speckles of one or more colors appearing on the background. Size of the spots can be varied. When used as a one-fire finish, the enamel is thin and usually has good thermal shock resistance. The finish tends to hide minor surface defects. For architectural panels, the pebbly texture gives a glossy easily cleaned surface which has poor object reflectivity and hence has a tendency to minimize objectional images and highlights. Applications: oven linings, roaster inserts, broiler pans, space heaters and cooking ware.

Production – One coat of finish porcelain enamel is applied over the entire area. Before it dries, enamel slip of a different color is applied to the wet enamel by stippling or spattering. This may be done by revolving a roller brush with enamel slip on the bristles under a scraper, so that large drops of enamel slip are thrown on the ware. Also, slip may be spattered on the surface with a stippling gun. Two or more colors of speckles or stipples may be applied in succession. The piece is then fired in the usual way. In some instances, the first finish coat may be fired before application of the speckles. The cost is relatively low especially if a finish suitable for one-fire application is used.

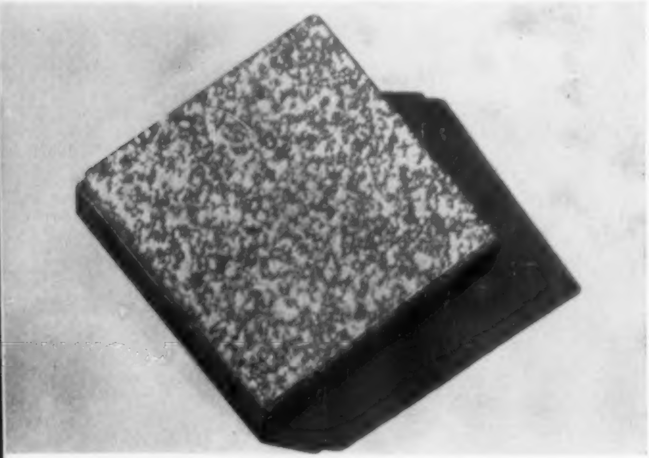
Veining or Veiling

Effect – A string or line pattern (sometimes in a spiderweb design) in a contrasting color is applied over a base color. Texture is smooth and usually glossy, but can be produced in low-gloss or semigloss enamels for special applications. This finish is suitable for flat or curved surfaces and offers an interesting decorative effect for large areas. Typical applications are appliances, housewares, stoves and interior architectural parts.



Production – A veining paste is prepared by grinding a flux and colorant in a high-viscosity vehicle to a stringy consistency. One coat of enamel is applied to the part and dried or fired. The paste is applied over the dried or fired part in a string or line pattern with a special spray gun which uses no atomizing air. Certain finishes can be applied in one firing operation, which is relatively inexpensive.

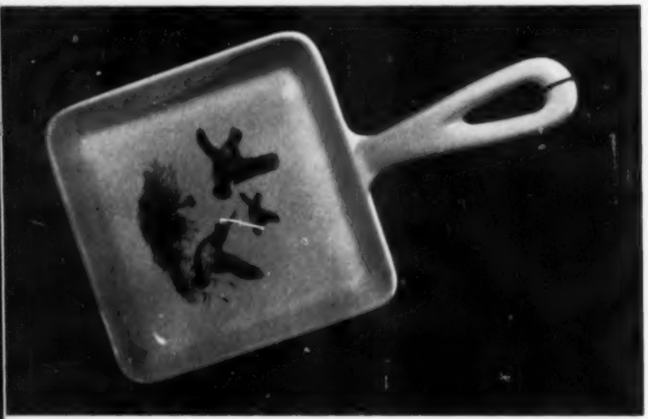
Polytone



Effect – A multicolor appearance or accentuated rough texture results from the shading produced by combinations of enamel. It offers an interesting multicolor textured surface, which does not produce distracting images. The finish can be produced in semigloss or gloss texture if desired. Typical applications are architectural panels, stoves and air conditioners.

Production – A rough texture is produced by dry spraying or stippling enamels of various colors. After drying, further color may be added by spraying a finely milled enamel of another color from one side at a small angle to the surface, thus coating one side of the protruding particles of the first coat.

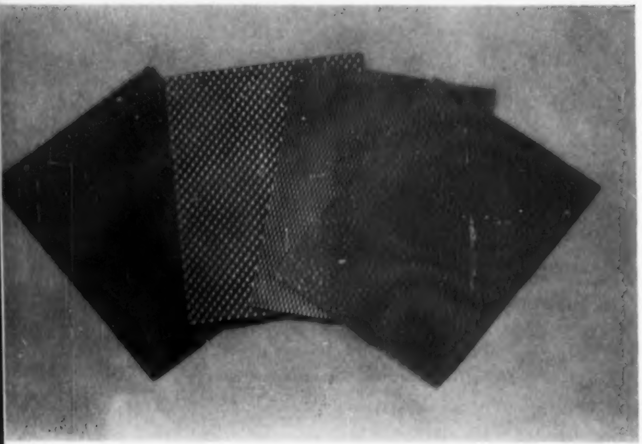
Decalcomanias



Effect – Small multicolor designs in fine detail are produced, usually in several colors. Finish is usually smooth and glossy. This is a good method for producing very fine detail in several colors. It can be used with any shape article and is useful for trademarks and lettered instructions. Designs are usually limited to small sizes.

Production – The decalcomanias are usually purchased from a supplier, who prints the design in ceramic pigments on transfer paper. The decalcomania is applied to a fired finish coat, then dried and fired.

Embossing



Effect – A variety of attractive finishes is possible in a patterned, raised design with variegated appearance, particularly when combined with other decorative techniques such as shadowing. Corrugated, Rigidized, pebbled, grained and other textured metals offer many possibilities. Embossing, in addition to giving interesting design effects, adds stiffness, minimizes objectional images in architectural applications, and provides a nonskid surface to the bottom of bathtubs or shower stalls. Other applications: telephone booth paneling, sinks, appliances.

Production – A special processed sheet is used in which the design is embossed in the metal before application of the porcelain enamel.

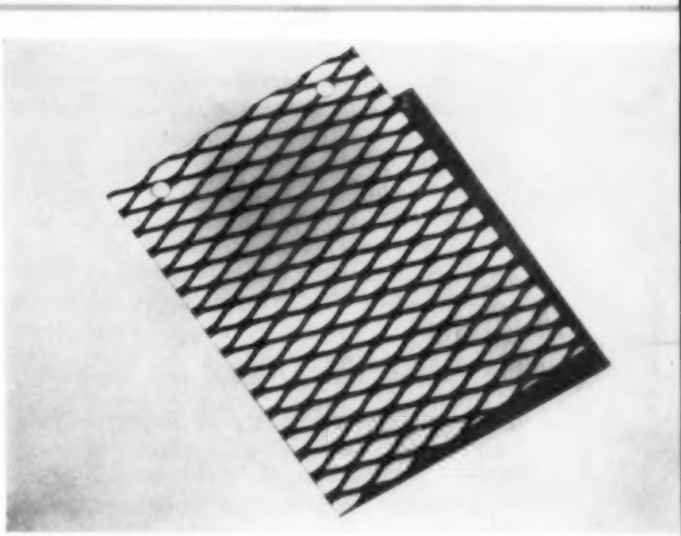
Printing and Silk Screen

Effect – Printing gives small designs or lettering, in fine detail, with reasonably sharp edges. The silk screen process offers a design in fine detail made up of areas of solid color, or dots of color in a halftone pattern, usually in glossy enamel, but sometimes in semigloss. Typical applications of the silk screen method are signs, intricate patterns, fine detail, halftone reproductions in color, small lettering, such as operating instructions and trademarks for appliances. Printing is usually suitable only for small designs.

Production – The ink for printing on porcelain enamel is similar to that for graining, but a vehicle is used to produce a tackier consistency. The ink is transferred to the dried or fired enamel surface with a rubber stamp. In the silk screen process, a stencil is prepared on a fine screen of silk or, more common today, a screen of fine corrosion resistant wire. The screening paste is forced through the open areas of the screen by a squeeze roll. The design is usually transferred to the screen by a photographic process. In the finished screen, meshes in those areas not to be coated are blocked, while meshes in areas to be coated are open. The design is usually surrounded by a wide margin. Labor cost per piece in the silk screen method is low, since the process is fast and unskilled labor can be used. The process is excellent where fine detail is required and is the only mass-production technique for multicolor halftone designs.

Symmetrical Patterns

Effect – The design is made up of a network of connecting lines. For example, expanded metal and other cutout patterns can be used to establish a design. The effect is desirable for architectural applications and for special decoration on appliance parts.



Production – The selected color for the line design is applied as a fully fired finish. The design (such as a piece of expanded metal) is placed over the finish and a contrasting color enamel is sprayed through the design using a small pattern-type spray, with the spray gun held at 90° to the surface. The mask is removed and washed and dried before re-using. The piece is then processed in the usual way.

Porcelain Enamel Finishes . . .

Base Metals for Enameling

Porcelain enamel is used on ferrous metals, aluminum and aluminized steel, stainless steel, copper and other nonferrous metals. Good flatness is a prime requirement for enameling sheet. Waviness or distortion has a tendency to be accentuated during firing. Highlights due to waviness are especially objectionable in enameled parts fabricated into architectural panels, stove, refrigerator and laundry cabinet outer panels.

For good formability, ferrous-base enameling stock should be of a soft, uniform temper. Proper surface texture is also needed. Through the years, iron enameling sheets have been produced with a rougher finish than is applied to cold rolled sheets which usually receive a paint finish. The rough finish was necessary so the proper weight of ground coat slip could be picked up in the dipping operation; also, the rough finish was thought to be necessary for good adherence because it added a mechanical bonding to chemical bonding at the enamel-steel interface. However, the need for a rough finish seems less important today and cold rolled steel is being used in many plants.

Sag Resistance – Sag is the inability of a piece of steel to support its own weight at elevated temperatures. It should not be confused with distortion due to relief of stresses caused by fabrication or to improper support during firing. Severe sag usually occurs when the metal is heated close to its transformation temperature (about 1630° F. at zero carbon content). However, as carbon increases, the critical temperature decreases, meaning that it is important to maintain low carbon content in enameling sheets for use with high-fire porcelain enamels. Carbon content should be limited to 0.07% in steels for conventional enameling.

One of the most important recent advances in porcelain enameling has been the development of lower-firing frits. Enamels that mature at 1400° F. or lower are a reality in many plants.

Low-Firing Enamels Will Extend Applications

Lower-firing frits have substantially the same working qualities as higher temperature frits. Good color, corrosion and acid resistance, thermal stability and resistance to damage by impact can all be had at lower firing temperatures. The cost of these frits is about the same as conventional ones and, with equivalent firing time, there need be no slowdown in production.

Less Warpage – The outstanding advantage of lower firing temperature is reduction in warpage. Expensive bracing can often be eliminated and lighter gage metals and nonpremium steels, such as cold rolled steel, can be used. Limitations are: (*a*) Ground coats formulated to fire at this low temperature require a nickel deposit of 0.04 to 0.06 g. per sq.ft. to assure adequate adherence, and (*b*) the lower fired ground coat will not withstand the many refirings which are required to make multicolored signs.

Refrigerator liners are ideally suited for low-firing frits. In many instances, it has been found that the reduction in warpage at the reduced temperature will allow the liner to be fabricated from cold rolled steel or will permit a reduction in the gage of enameling iron. The extremely low warpage of the 1400° F. cover-coat frits also shows another savings by reducing the chipping of parts on the assembly line and in shipping and installation. Lower temperature covercoats for refrigerator liners are color stable and are rated "A" in acid resistance. In many plants firing of ground coat and cover coat is done with the same time-temperature cycle.

Appearance Is Good – Low-temperature enamels are available for sheet steel which fire in the range 950 to 1450° F. They are mostly in the range of 1300 to 1400° F. and both lead-bearing and lead-free enamels are produced. In appearance, enamels fired between 1200 and 1350° F. are nearly identical to conventional ones. They have good reflectance and there's ample latitude for matching colors. Enamels fired below 1200° F. tend to resemble organic finishes. A very fine type of orange peel is often present, but the finishes have a pleasing appearance, although reflectivity is lower.

Porcelain on Aluminum and Stainless Steels

New enamels have been developed for aluminum and stainless steels. One advantage of these metals, particularly for architectural uses, is that panels can be cut, punched, and drilled without danger of corrosion to the underlying metal at points of exposure. For special decorative effects, interesting combinations of polished metal and porcelain enamel are also possible.

Because of its light weight, good functional properties and decorative appeal, enameled alu-

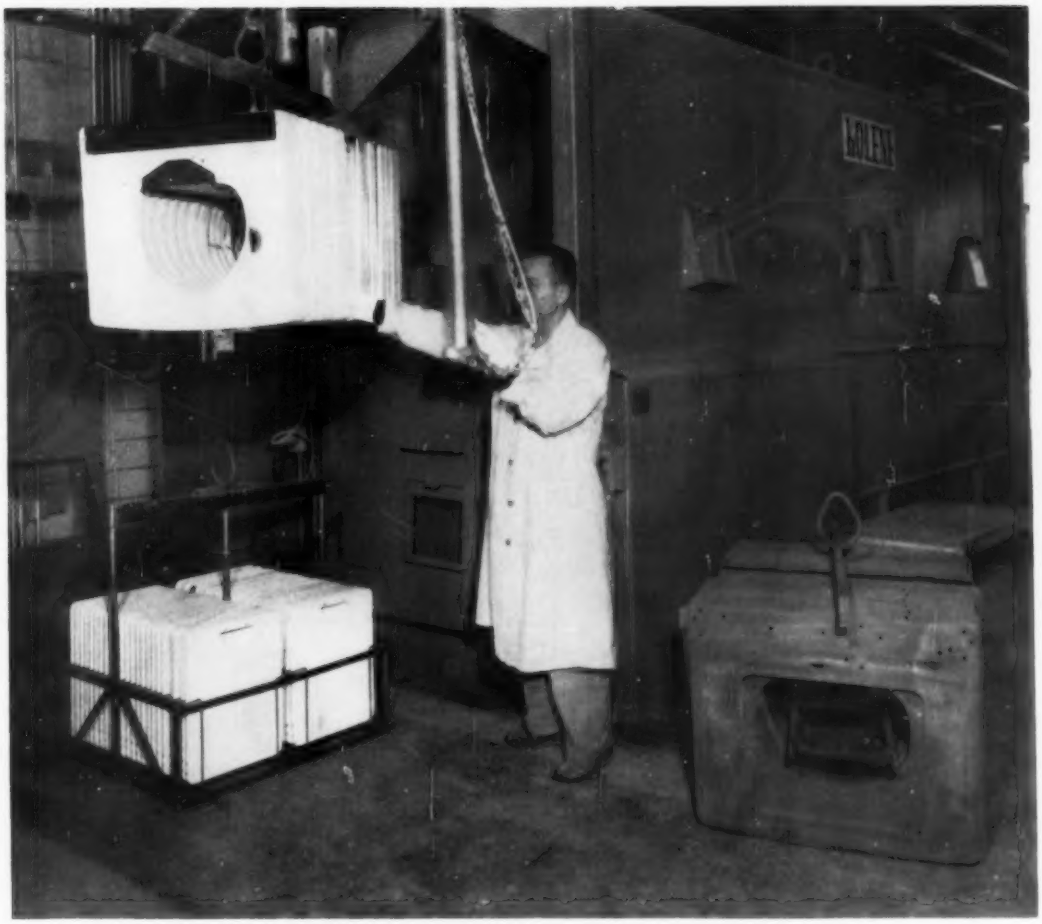


Fig. 3 – A New Process for Removal of Porcelain Enamel From Reject Parts Utilizes a Molten Salt Bath. A typical treatment is 10-min. immersion in molten salt, rinse in hot water, then return to re-enameling cycle. (Courtesy Kolene Corp.)

minum is growing in popularity. The selection of the aluminum alloy, whether it be a sheet product, casting or extrusion, should depend on the use of the fabricated part. Since the firing temperature is well above the annealing temperatures for the common aluminum alloys, care must be taken to select an alloy which will have the mechanical properties needed for the application. Heat treatable aluminum alloys age harden at the maturing temperature of porcelain enamels. Thus they are recommended for applications requiring maximum mechanical properties in the finished condition. High-strength heat treatable alloys, such as 2024 or 7075, may be porcelain enameled if firing temperature does not exceed 920° F.

Alloys Recommended – The following aluminum alloys are recommended for enameling: sheet – 1100, 3003, 6061; extrusions – 1100, 3003 (non-heat-treatable) and 6061, 6062, 6063 (heat treatable); castings – 43 (non-heat-treatable) and 356, 344 X (heat treatable). Alloy 6061 is considered best for general applications especially for architectural uses. Wrought alloys in special enameling grades as sheet and extrusions are now available commercially (see *Metal Progress*, October 1958, p. 116).

Properties of enamels for aluminum are quite similar to low-temperature enamels for steel, previously discussed. They are glasses with a high coefficient of expansion, formulated to be fired in the range 925 to 975° F. A variety of colors are available, from the light pastels to the darker hues. Texture of the enamel can be varied from a high gloss to a dull matte with special effects as shown in the illustrations.

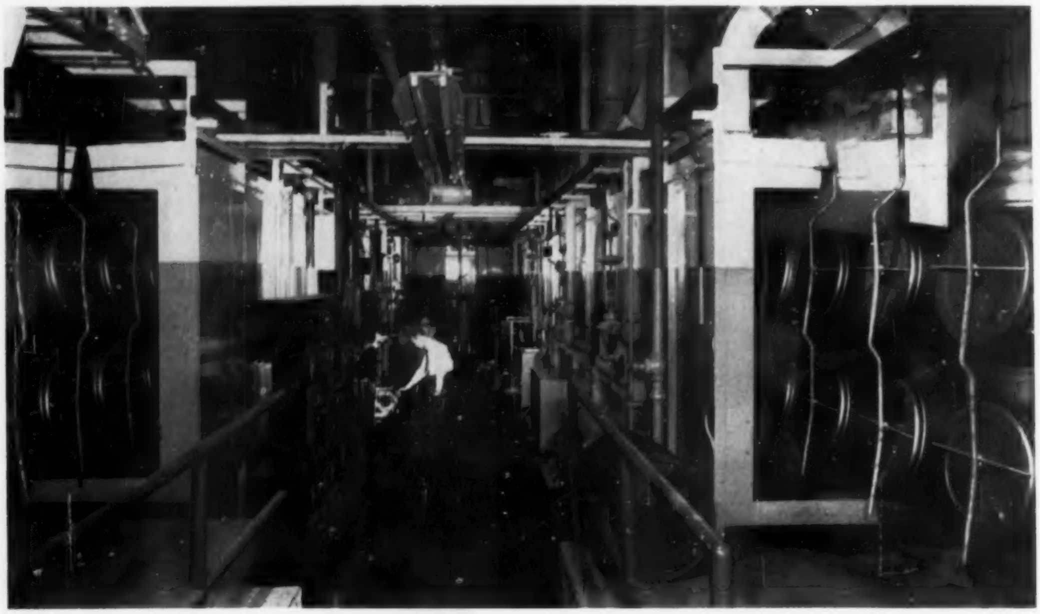


Fig. 4 — Continuous Production Lines Utilizing Conveyers and Automatic Cleaning and Pickling Are Becoming More Common in Porcelain Enamel Finishing

Enameling is being done on aluminum-coated steel. The advantage here is that the part has the corrosion resistance of an aluminum surface along with the strength and distortion resistance of the steel base.

One-Coat Enamels

Premium grades of enameling steel have been developed which permit the porcelain enamel cover coat to be applied directly to the base metal without use of a ground coat. In addition to cost reduction, another advantage is the reduction in over-all thickness of the coating. This improves resistance to mechanical damage and gives better thermal shock properties which have added to the durability of porcelain enamel on a number of new products.

Ordinarily when a cover coat is applied directly to a ferrous base metal, surface defects crop up. This condition is prevented in special one-coat enameling steels, such as "Ti-Namel" developed by Inland Steel Co., by stabilizing the carbon with titanium. This material, although higher priced than other enameling stock, has exceptional sag and warp resistance and is especially suited for large enameled panels such as range platforms. Inland is working on a lower priced, single-coat enameling iron called "One-Cote". Armco Steel Corp. has been field testing "Uni-vit", a steel developed for one-coat one-fire enameling.

White and Colors Too — In general, conventional cover-coat enamels can be applied directly to these special steels. The colors which can be used are somewhat limited; white is by far the most popular. An appliance maker told *Metal Progress* that he will soon go into production with a one-coat blue porcelain finish on laundry equipment and perhaps toasters. A large number of range panels are produced with one-coat white. In some instances, cold rolled steels are used, but special attention is given to metal preparation. In one plant, care is taken to see that the cleaner is thoroughly rinsed from the work, and treatment in 25% phosphoric acid is used in a spray pickling machine to give a uniform surface etch. The nickel flash is carefully controlled to assure even deposition of a thin nickel coating. Several manufacturers using porcelain enamel finishes are engaged in research programs to further develop enameling irons and cold rolled steel for the one-coat process. While much remains to be done before ordinary base metals will be suitable for production-line methods, there is a feeling of optimism that this goal is within the reach of the finishing industry.

Improved methods of pickling and cleaning metal parts before porcelain enameling have

been developed; in many instances, the operation is completely automatic. New techniques are also being used in spraying and dipping. An automatic dipping machine can be used for ground and cover coats on hollow ware, or ground coat on flatware. Still another method designed to reduce costs is the flow coat process (see *Metal Progress*, May 1959, p. 84).

Electrostatic spraying is helping production engineers mechanize their operations and reduce costs. Here the underlying theory embodies the simple electrical principle that two bodies which carry the same electrical charge will repel each other, while two having opposite charges will attract. Applied to spraying this means that particles of coating material which have been charged to a negative polarity will tend to seek out and deposit on an object which is held at the opposite (positive) polarity.

Mechanized spray methods are available which can be adapted to any production requirement. The selection of method depends on many factors such as product mix, production rate and local labor situation.

The design of enameling furnaces is also changing. As a result of low-temperature firing of both steel and aluminum, the forced convection heated enameling furnace has evolved. These furnaces are either continuous or intermittent box-type which give better control of temperature and permit the ware to be laid down or suspended along conveyers.

Many porcelain enameling operations are conveyerized. Production lines take the ware from metal fabrication and cleaning, through spray booth and dryer, to the furnace for firing, and on to the assembly and packing rooms with a minimum of manual handling.

Tests for Quality – The user of porcelain enamel is now able to judge more accurately the quality of his product through closer control of processing and use of test methods for measuring the properties of the coating. Porcelain enamels may be evaluated for their acid resistance and rated AA, A, B, C, and D. Test equipment has also been developed to judge abrasion and alkali resistance, impact strength, water resistance, adherence, gloss, reflectance and color.

All these improvements in porcelain enameling – mechanization, new processes, improved equipment, and test methods – have a direct bearing on quality of the finished product. Coupled with improvements in frits and base metals, they add up to a more functional coating with greater decorative possibilities than was possible in the past.

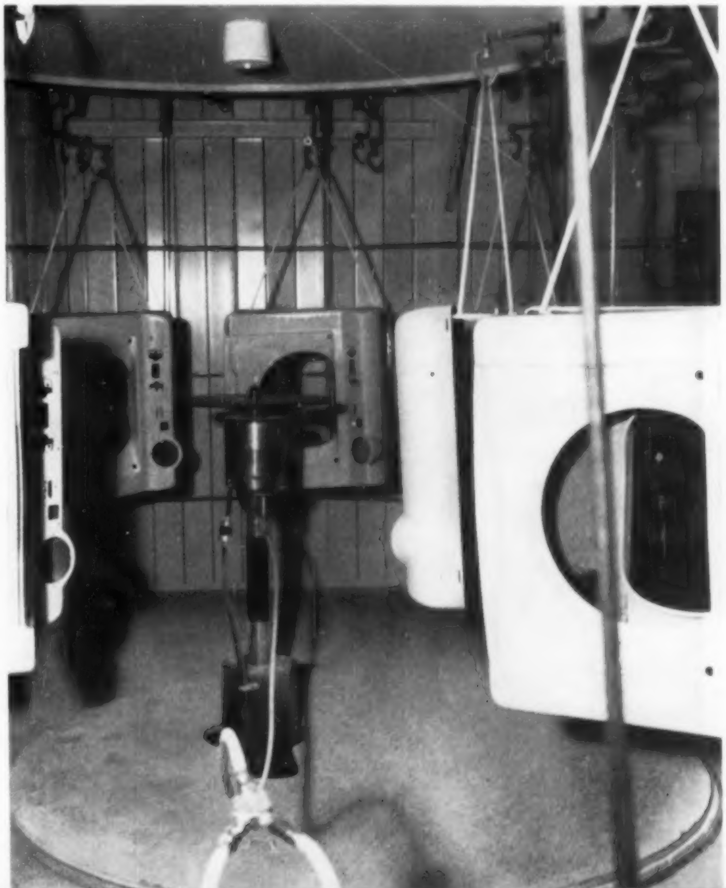


Fig. 5 – An Important Part of the Trend Toward Mechanization Has Been Greater Use of Automatic Spraying. (Courtesy Whirlpool Seeger Corp.)

Improvements in Plating Zinc Die Castings

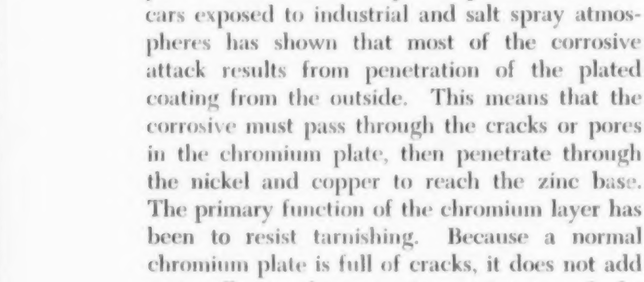
STAFF REPORT

A double layer of nickel of the duplex type in place of regular bright nickel gives chromium-plated zinc die castings with improved corrosion resistance. Bright, crack-free chromium in place of regular chromium also increases durability of the finish. (L17; Zn, *Ni*, *Cr*, 5-61)

THE LIFE of zinc die castings plated with the bright "chrome" finish so familiar on today's cars is only as good as the copper-nickel underplate. Examination of plated parts taken from cars exposed to industrial and salt spray atmospheres has shown that most of the corrosive attack results from penetration of the plated coating from the outside. This means that the corrosive must pass through the cracks or pores in the chromium plate, then penetrate through the nickel and copper to reach the zinc base. The primary function of the chromium layer has been to resist tarnishing. Because a normal chromium plate is full of cracks, it does not add materially to the corrosion resistance of the bright part.

In making these observations in a recent Research Bulletin of Doehler-Jarvis Div. of National Lead Co., M. R. Caldwell, manager of electroplating and finishing for the division, suggests three methods for improving durability of bright, chromium-plated zinc die-cast parts: One is to improve the protective value of the chromium plate by eliminating cracks and by increasing its thickness, producing what's termed a "crack-free chromium" plate. A second approach, which Mr. Caldwell claims is expensive and not always effective, is to increase the thickness of the nickel plate. Even with heavier deposits of bright nickel, early failures have been found. A third approach, which Doehler tests have proven to be best, is to use a double plate of nickel.

Fig. 1 – Photomicrograph Shows Banded Structure of Bright Nickel Plate and Columnar Structure of Semibright Nickel. 1000 ×. (All photographs courtesy Doehler-Jarvis Div., National Lead Co.)



The Double-Plate Process

The double plate refers to the nickel deposit applied over an initial copper plate. The nickel plate consists of a layer which is semibright followed by a top coat which is full bright, to develop the decorative finish. The semibright coating, which is from 60 to 75% of the total nickel thickness, is plated from a so-called "sulphur-free" bath. This means that the brightener does not contain sulphur-bearing organic compounds.

According to Mr. Caldwell, with this type of semibright nickel, corrosive materials do not penetrate the coating as fast, and the over-all life of the plate is increased as much as 33%. A typical plating sequence used in the Doehler double-plate method is copper, 0.0004 in.; nickel, 0.0008 in. (total); and chromium, 0.000010 in.

The nickel plate would consist of 0.0006 in. plated from a semibright, sulphur-free bath followed by 0.0002 in. from a full bright bath.

Figure 1 shows the banded structure of the bright nickel layer and the columnar structure of the semibright nickel in a typical double plate. When no sulphur-bearing brighteners are used, the semibright nickel has a different grain structure entirely. The columnar structure is similar to that from a Watts nickel plating bath, which is known to be more resistant to corrosion than a full bright nickel coating.

Figure 2 shows how the double nickel coating performs in a corrosion test. The corrosive attack is slowed so much by the semibright layer that the corrosion process is forced to spread laterally instead of proceeding vertically through the deposit to the base metal. (The improved corrosion resistance of duplex nickel plate was discussed in *Metal Progress,* June 1958, p. 95.)

Production Experience

In August 1957, Doehler-Jarvis installed the double plating system in a large copper-nickel-chromium automatic plating machine. Parts on 1958 model cars plated with double nickel were found to be superior to parts plated by the regular process using bright nickel. Using the double-plate method, no difficulty is being encountered in meeting the new accelerated corrosion tests which the automotive companies now specify. In recessed areas on complicated parts, where thickness is somewhat below the minimum specified, the accelerated corrosion tests are easily passed whether it be the Corrodekote test or accelerated acetic acid salt spray. Mr. Caldwell predicts that these recessed areas will give better corrosion performance in the field when plated with double plate than with normal bright nickel.

A series of corrosion tests was run by an automotive company in Detroit to compare parts finished with double plate with those using two standard bright nickel plates. Figures 3 and 4 show the results of these tests. Parts plated by the double-plate method stood up perfectly for 34 days on the roof without any corrosion spots. Parts plated in regular bright nickel baths showed many corrosion spots which went through to the base metal. The double plate also showed up much better in both the acetic acid salt spray and the copper accelerated acetic acid salt spray tests (Fig. 5).

When tested for eight days in neutral salt spray, both regular and double plates looked bad. Mr. Caldwell surmised that this reflects the inaccuracy of the regular salt spray test which corrosion experts condemn for its inability to duplicate normal corrosion conditions.

Crack-Free Chromium Method

Research is being sponsored by the American Zinc Institute at Battelle Memorial Institute to investigate several plating procedures for improving corrosion resistance of electroplated die castings. One area which is being studied is the deposition of bright crack-free chromium in place of regular chromium plate*. By comparison with regular chromium, bright crack-free chromium has a broader plating range and gives improved corrosion protection provided sufficient thickness is deposited.

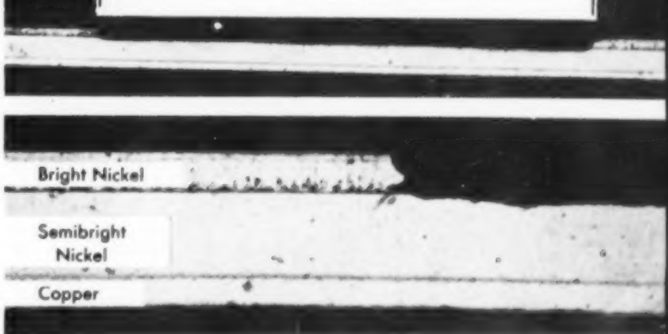
The appearance and corrosion resistance of automotive hardware made from zinc die castings plated with copper-bright nickel-chromium at the plant of Nelmor Mfg. Co., Cleveland, were improved by adopting bright, crack-free chromium in place of regular chromium.

Duplex Nickel Investigated

The Battelle work to improve corrosion resistance of plated die castings also included several types of duplex nickel coatings. One system studied consisted of 0.0004 in. copper, 0.0008 to 0.0009 in. duplex nickel and 0.00002 in. regular chromium. Four out of five panels checked in salt spray and all five panels evaluated by Cor-

*Regular chromium is usually plated at 150 amp. per sq.ft. in a bath containing 33 oz. per gal. chromic acid and 0.33 oz. per gal. sulphuric acid maintained at 105 to 110° F. Bright crack-free chromium was plated from the modified ratio bath containing 33 oz. per gal. chromic acid and 0.21 oz. per gal. sulphuric acid at 130° F. with current density of 300 amp. per sq. ft. Bright crack-free chromium may also be plated from a self-regulating bath developed by Metal and Thermit Corp.

Fig. 2 – Section Through Pit Shows Corrosion Through Chromium and Bright Nickel Plate. The attack spreads laterally, indicating resistance of semibright nickel to penetration. Upper view at 250 ×, lower 1000 ×



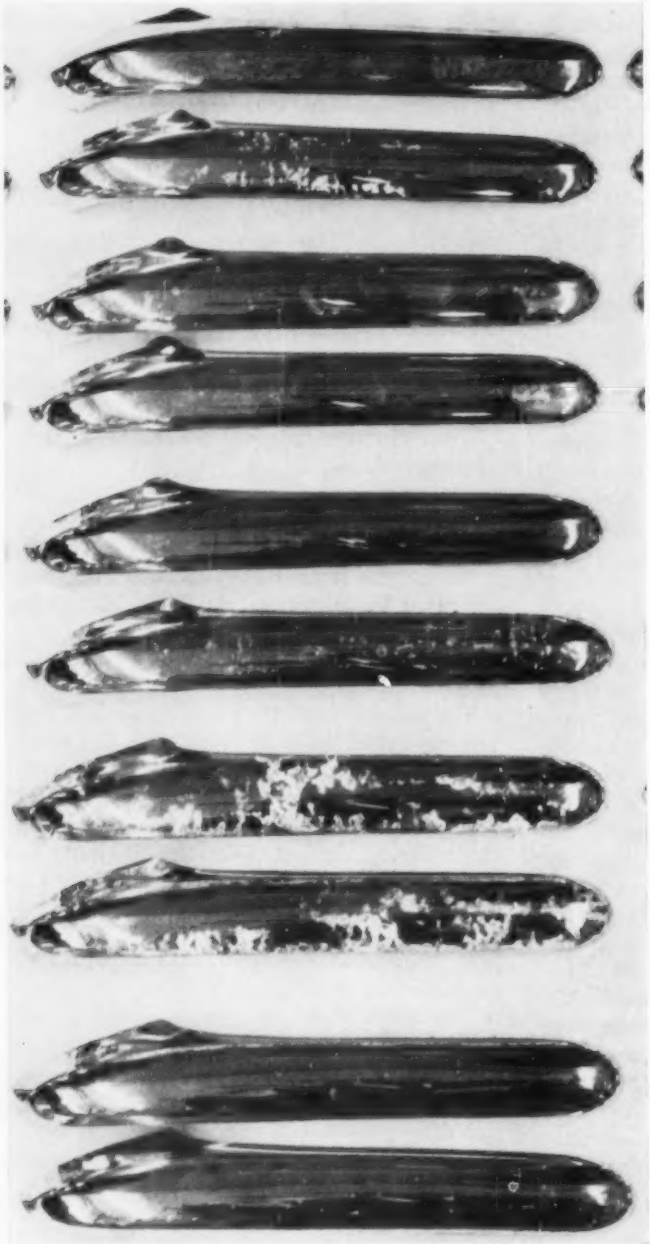


Fig. 3 – Corrosion Tests on Bright-Plated Zinc Die Castings Using Regular Nickel

rodekote testing showed no blistering or base-metal corrosion. Panels in this system, plated similarly except for reduction in chromium plate thickness to 0.00001 in., also showed no blistering or base-metal corrosion but were pitted after two cycles of Corrodekote testing. (It's probably true that less thickness of chromium would be required over duplex nickel than over regular bright nickel.)

Judging by results of both Corrodekote and outdoor weathering for a nickel composite with a bright, crack-free chromium plate, the Battelle workers feel that surface pitting in duplex nickel plate can be prevented by plating with crack-free chromium. They postulate that a composite consisting of 0.0008 in. or more duplex nickel and

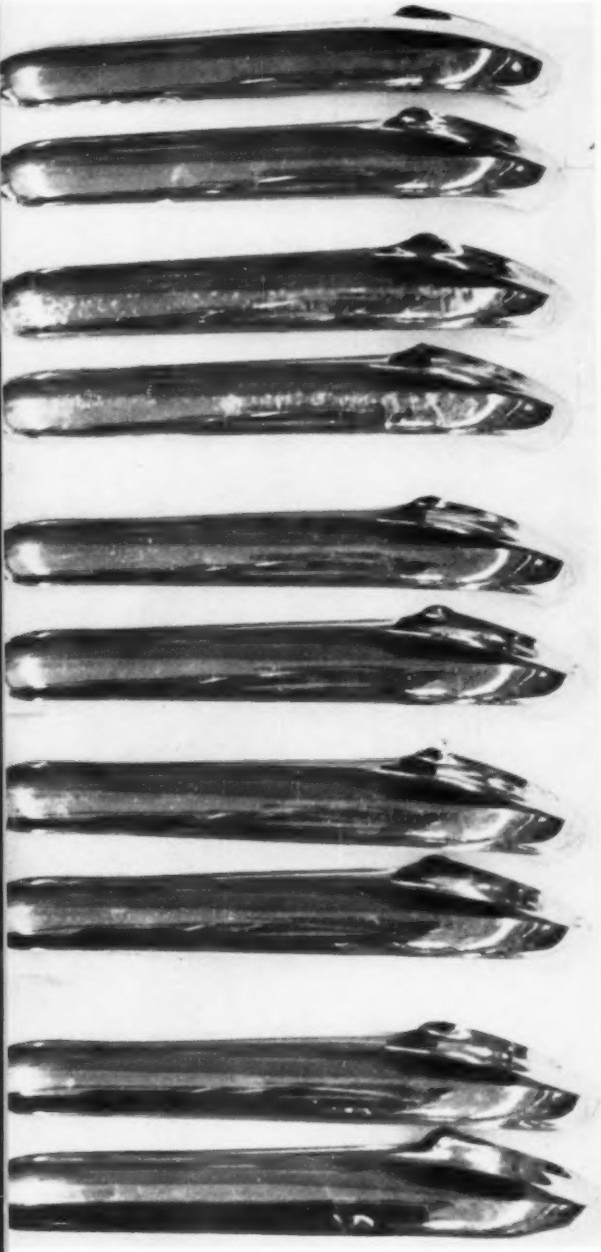


Fig. 4 — Corrosion Tests on Bright-Plated Zinc Die Castings Using Double Nickel

0.000025 in. or more bright, crack-free chromium should furnish excellent resistance to base-metal corrosion and surface pitting in the nickel plate. Future work is planned to study such composites more thoroughly. (An article in *Metal Progress* in the near future will give procedures for reducing costs and improving corrosion resistance of electroplated die castings based on the Battelle-American Zinc Institute work.)

Corrosion Investigation Confirms Mechanism

Battelle examined automotive parts of plated die castings which were removed from service or from three-month roof exposure periods. Evidence shows that the first stage of corrosion occurs in the nickel plate. Pits in the nickel are initiated at pores or cracks in the chromium by the unfavorable nickel-chromium galvanic couple. Some nickel coatings corrode laterally when the pits reach the copper interface. The copper plate is perforated eventually, exposing the zinc base metal, which corrodes rapidly. Bulky corrosion products close off the pits and exert pressure under the surrounding areas, raising blisters.

Fig. 5 — These Bright-Plated Die Castings Were Tested for 20 Hr. in Copper Acetic Acid Salt Spray to Compare Regular Plate With Doehler Double Plate. (Top) Cu 0.0004 in., regular nickel 0.0008 in., Cr 0.00001 in.; (bottom) Cu 0.0004 in., double nickel 0.0008 in., Cr 0.00001 in.

After the Shotting Process, Shot Particles Are Removed From Quench Tank and Carried by Conveyers to the Heat Treating Operation

Progress in Finishing

What Makes a Good Steel Shot

*By CHARLES E. CARLIN**

Microstructure is a good clue to the life of shot used in blast cleaning or peening metal parts. Life, hardness and size distribution of the shot affect the efficiency of blasting operations. (W2a, L10c; ST)

SINCE the introduction of fully heat treated cast steel shot, users of shot-blasting equipment have been able to realize lower costs. Three factors interact to determine the performance of a steel shot in a blasting operation. They are hardness of the shot, its life, and size.

Hardness Is Important

Soft pellets perform inefficiently because the energy of impact is dissipated by plastic deformation which occurs when they strike the work. This means that, to achieve cleaning, the blasting operation must be prolonged. In some instances, it may be impossible to clean with soft shot. An example is work with cavities and recessed areas not exposed to direct blast. These areas usually depend upon rebounding abrasive particles for thorough cleaning.

Properly heat treated shot should have good toughness and proper rebound characteristics with an average hardness of Rockwell C-45 or higher. The hardness range should be restricted to assure uniform performance.

Life and Size of Shot

Shot life and size are so closely related that they cannot be considered separately. The life of the shot determines its ultimate cost. But equally important, the life of the shot influences its size distribution in the machine. Keep in

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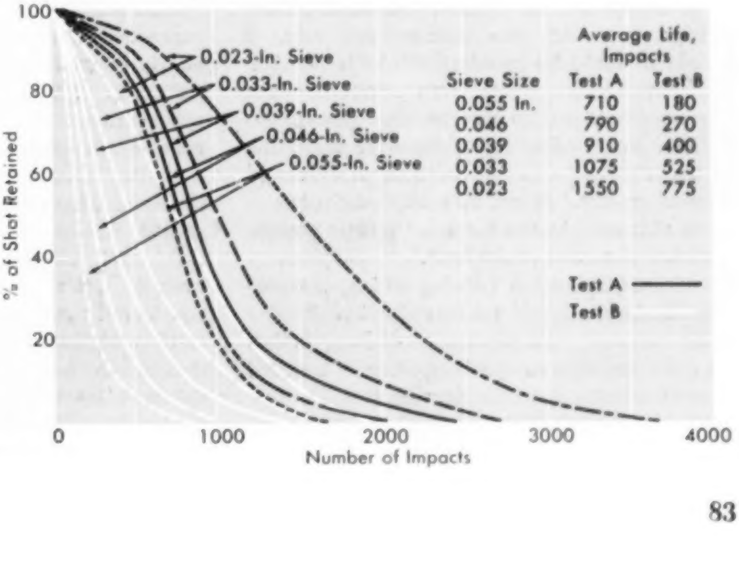


Fig. 1 – Breakdown Curves of S.A.E. 550 Cast Steel Shot. The life of Sample B would be double that of Sample A if all the pellet fragments were removed when they were reduced in size so they passed the 0.023-in. sieve

mind that it is the operating mix of shot in the machine which does the cleaning job.

For example, consider a typical shot-blasting operation. There is an optimum range of shot size for blasting efficiency. New shot is charged into the machine where it is retained until, through repeated fracturing, it has been reduced to some predetermined size. It is then removed from the machine and replaced by more new shot. As the blasting operation proceeds, the rate of addition of new shot and removal of fines becomes constant, and the size distribution of the operating mix is stabilized.

Evaluating Shot Life

When shot pellets are broken down in a shot testing machine, characteristic breakdown curves are obtained. This is done by subjecting the shot pellets to a sieve analysis at given intervals and plotting the percentage of shot retained on sieves of different sizes versus the number of impacts against the work, as determined by the shot testing machine. The average number of impacts required to break new shot pellets down to fragments which pass any given sieve is obtained by measuring the area under the curve corresponding to that sieve. This average number of impacts is called average life.

The marked degree of variation in the performance of two samples of different S.A.E. 550 cast steel shot is indicated by the breakdown curves in Fig. 1. Both samples were screened to obtain size fractions which passed through a 0.078-in. sieve and were retained on a 0.066-in. sieve. These fractions were then broken down in a shot testing machine. The average number of impacts required for breakdown through the different sieve sizes is given on the curves.

The significance of this test is that, in a shot-blasting operation, the consumption rate of Sample B would be double that of Sample A if all the pellet fragments were removed when they were reduced in size so they passed the 0.023-in. sieve. For larger removal sizes, the relative consumption rate of Sample B would be even greater. It can be seen that Sample A resists reduction in size for a far greater portion of its life than does Sample B. In an ordinary shot-blasting operation (during which shot particles undergo considerable reduction in size before removal), the percentage of large pellets in a stabilized operating mix of Sample A would be much greater than for Sample B.

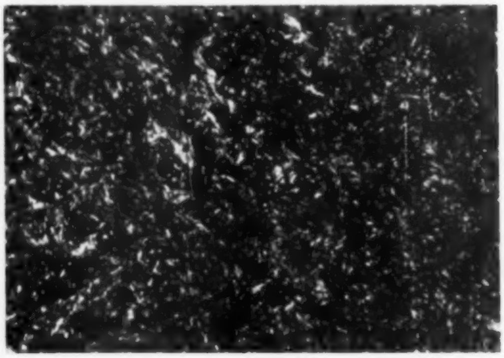
When cast steel shot is properly heat treated, the rate of consumption is low for a given removal size. At the same time, the percentage of large pellets in a stabilized operating mix is high. The low consumption rate means low shot costs. The favorable size distribution of the operating mix, coupled with the relatively high, uniform hardness, means reduced blasting time. The combination of low cost and reduced blasting time gives maximum economy.

Shot Testing

The user of blast cleaning equipment should test steel shot for hardness, life, and size.

Microstructure Is Clue

Structure of Tempered Martensite and Bainite Gives Longest Shot Life.



Sieve Size	Average Life of Steel Shot
0.046 in.	840 impacts
0.039	920
0.033	1010
0.023	1390

Hardness – The hardness specimen is prepared by mounting the shot pellets in a rigid matrix (bakelite is suitable), then grinding and polishing. Measurements may be made with any instrument capable of determining the hardness of very thin sections. The Tukon tester with the Knoop indenter, which makes large, shallow indentations under light loads, gives reliable results.

In interpreting the hardness data, both the average and the range of hardness should be considered. An average hardness of Rockwell C-45 or higher is desirable. The range of hardness should be restricted.

Life – Unfortunately, the direct measurement of shot life is beyond the scope of most quality control laboratories. Shot breakdown is a com-

plex process. Laboratory measurement of shot life requires carefully calibrated equipment. Without the proper equipment, breakdown tests are usually meaningless. However, a reasonably valid appraisal of shot life may be made by examining the microstructure of shot pellets and the nature of shot breakdown.

Cast steel shot, properly heat treated, will withstand a number of impacts during normal usage before breakdown. However, the pellets suffer fatigue damage and eventually fracture. In Fig. 1, the curve for the breakdown of the shot through the 0.055-in. sieve illustrates this fatigue and fracturing sequence. Initially, few fractures occur, and the breakdown curve slopes gently. However, after the pellets have sustained a number of impacts, they succumb to fatigue damage. Wholesale fracturing then occurs, as indicated by the change in the slope on the breakdown curve. Structural inhomogeneities in the shot particles act as stress-raisers and cause a marked increase in the rate of breakdown.

Microstructure Reveals Shot Life

The microstructure of cast steel shot which has been properly heat treated should consist of tempered martensite and bainite, highly refined and homogeneous as shown in the photomicrograph at left on p. 84. The presence of excess carbides (center micrograph) or constituents segregated at the grain boundaries (photomicrograph at right) is undesirable. The average lives of several samples of cast steel shot with microstructures typified by each of the three photomicrographs are given in the tabulations below the micros. These samples varied in average hardness from Rockwell C-44.9 to 46.2. The carbon content varied from 1.03 to 1.11%. All three samples were screened, and only the fractions which passed a 0.066-in. sieve and were retained on a 0.055-in. sieve were tested.

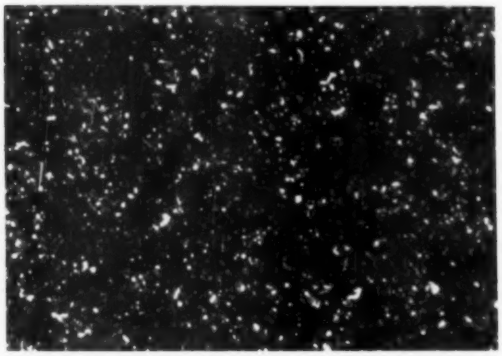
Size – The size of new shot is determined according to the specifications established by the S.A.E. However, the most important consideration is the size distribution of the operating mix. This depends upon the breakdown characteristics and removal of the shot size.

Two lots of different steel shot may be quite similar in size distribution; however, differences in microstructure may affect their breakdown characteristics in such a manner that they will yield operating mixes of marked differences in size distribution.

These few tests incorporated into a quality control program will indicate whether or not a steel shot is satisfactory from the standpoint of hardness, life, and size.

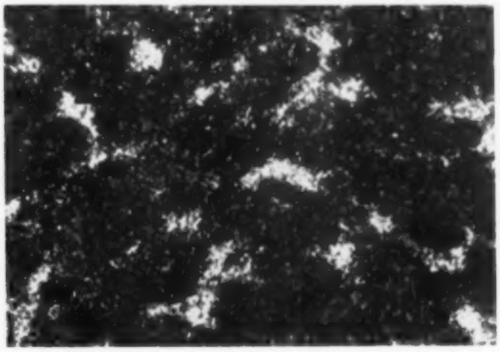
to Life of Steel Shot

Tempered Martensite and Excess Carbide Gives Diminished Shot Life

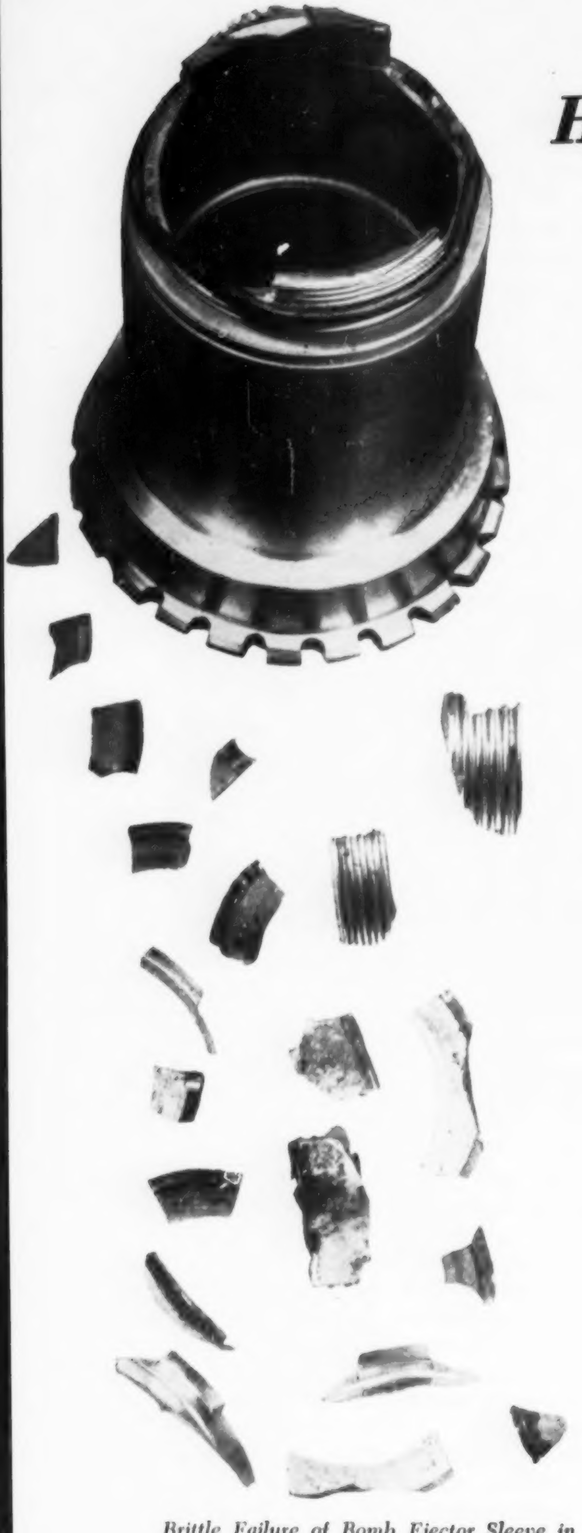


Sieve Size	Average Life of Steel Shot
0.046 in.	500 impacts
0.039	640
0.033	780
0.023	1150

Tempered Martensite With Retained Austenite, Cementite and Bainite at Grain Boundaries Gives a Relatively Short Shot Life. Etch 2% Nital; 500 × for all structures



Sieve Size	Average Life of Steel Shot
0.046 in.	290 impacts
0.039	410
0.033	545
0.023	825



Brittle Failure of Bomb Ejector Sleeve in Firing Test. Austenitized and quenched in dissociated ammonia, this part was embrittled by hydrogen and carbide precipitation

How to Avoid Trouble

TYPE 431 STAINLESS STEEL, when properly melted and processed, is a valuable structural alloy. As steel alloys go, it is exceptionally isotropic in both strength and ductility. When fully hardened to a minimum tensile strength of 200,000 psi., it offers the best corrosion resistance of all the hardenable stainless steels, including even the precipitation hardening grades. On the other hand, if improperly melted or complacently processed or both, it can become a metallurgist's nightmare. Even though procured and processed to government specifications, the metal may be extremely anisotropic, catastrophically brittle, and susceptible to intergranular corrosion. If these difficulties and pitfalls are to be avoided, meticulous attention to all processing details is essential.

Effect of Delta Ferrite

The alloy was introduced into the United States from Great Britain during World War II when the Controlled Materials Plan was in effect. Since nickel was one of the alloying additions most closely controlled, melters aimed the nickel content toward the low side of the allowable range (see Table I). This immediately started

Table I–Chemical Analysis of Type 431

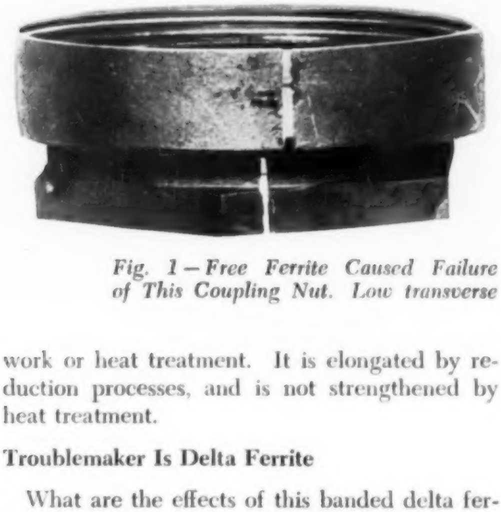
	MIL-S-18732	20% Ferrite	Ferrite-Free
Carbon	0.12 to 0.17%	0.16%	0.16%
Manganese	0.30 to 0.80	0.60	0.60
Silicon	0.20 to 0.60	0.30	0.30
Chromium	15.00 to 17.00	16.95	15.60
Nickel	1.50 to 2.50	1.90	2.30
Nitrogen	—	0.03	0.07

With Type 431 Stainless

By C. C. ANGSTADT*

Though this martensitic stainless steel has excellent strength and corrosion resistance when properly melted and fabricated, it is difficult to process. Careful heat treatment in hydrogen-free atmospheres is essential to eliminate austenite and prevent embrittlement. Fabrication methods are similar to those needed for the 18-8 stainless types. (J-general, G-general; SS)

the alloy off on the wrong foot. Deliberate melting of Type 431 to conserve nickel results in a product with a heat treated microstructure consisting of martensite plus significant amounts of stable delta ferrite. This is caused by a higher chromium content than is soluble in the prior austenite. Formed by chemical segregation occurring during solidification of the ingot, ferrite never transforms during subsequent hot work or heat treatment. It is elongated by reduction processes, and is not strengthened by heat treatment.



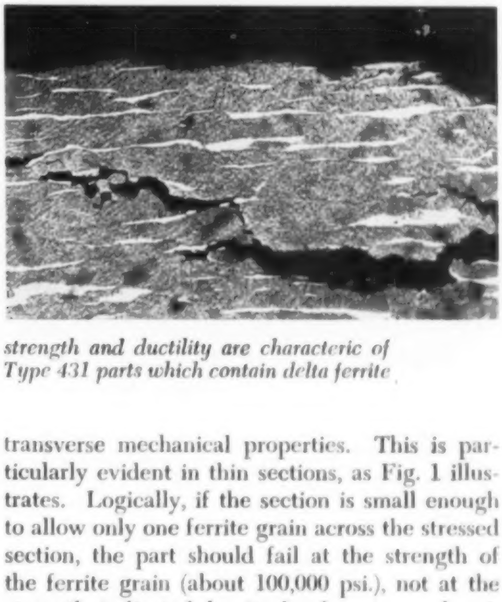


Fig. 1 – Free Ferrite Caused Failure of This Coupling Nut. Low transverse strength and ductility are characteric of Type 431 parts which contain delta ferrite

Troublemaker Is Delta Ferrite

What are the effects of this banded delta ferrite in a hardened part of this steel? Some of them are beneficial, but most are detrimental. Because of its low strength, deformation of delta ferrite absorbs some of the stresses developed during hardening. This lowers residual tensile stresses and minimizes susceptibility to cracking. Its extended straight-line grain boundaries act as barriers and inhibit propagation of transverse cracks. However, the converse is also true. Under transverse loads, these same straight-line grain boundaries provide ideal paths for crack propagation parallel to the direction of rolling. Furthermore, the ferrite is virtually a continuous "weak link" phase; material containing it has low transverse mechanical properties. This is particularly evident in thin sections, as Fig. 1 illustrates. Logically, if the section is small enough to allow only one ferrite grain across the stressed section, the part should fail at the strength of the ferrite grain (about 100,000 psi.), not at the strength indicated by its hardness or a longitudinal tension test.

As previously mentioned, ferrite is formed by chemical segregation during solidification of the ingot. Containing more chromium and less nickel and carbon than the matrix grains, it is

*Assistant Chief Metallurgist, Douglas Aircraft Co., Inc., El Segundo Div., El Segundo, Calif.

cathodic to the matrix grains. Consequently, its presence lowers corrosion resistance. Ferrite, and the chemical composition which produces it, also affects oxidation resistance, forging, welding, cold heading and elevated-temperature properties, among others.

No Effect on Fabrication

Generally, Type 431 which contains delta ferrite is easily fabricated. With relatively good machinability in the hardened condition, it can be turned, milled, drilled, roll threaded and ground without much difficulty. It is also unlikely to retain austenite or crack on quenching.

Though machinability is good, performance of fabricated parts is another thing entirely. If a part could be designed to be loaded in the longitudinal direction exclusively (free from stress concentrations) and properly processed, it would perform admirably. Obviously, such a part is quite a rarity. Thin-walled pressure vessels and other transversely stressed items containing large amounts of ferrite fail at surprisingly low loads. The fracture characteristics of such failures (though ductile by academic definition) are woody in appearance, associated with virtually no detectable plastic deformation, and progress in straight lines adjacent to and through the ferrite grains. The crack progresses so rapidly that the failed part invariably winds up in two pieces. Cylindrical parts crack from one end to the other. Fatigue and stress-corrosion failures invariably start as longitudinal cracks, even though the major load vector may be parallel to the longitudinal direction.

Ferrite-Free Steel

Stable banded delta ferrite (Fig. 2) cannot be removed from Type 431 stainless (once it is cast into ingots) by any known metallurgical process. It can be produced without ferrite, however, by proper control of chemical composition during melting (Fig. 2). Nickel and carbon are maintained on the high side of their allowable ranges to open the gamma loop (this increases the solubility of chromium in the austenite); chromium is kept on the low side to provide a further guarantee. As an additional precaution, the melter allows the molten steel to absorb a small amount of nitrogen. This element, the most potent austenite stabilizer of all alloying additions, is not controlled by present commercial government specifications (Table I), and (unlike carbon) does not reduce corrosion resistance.

Ferrite-free steel, produced as described, does not always exhibit a wholly martensitic structure as received from the mill or as hardened by the user. It is essentially devoid of delta ferrite, as its name implies. However, if the melter adds more austenite-stabilizing elements than required to balance the ferrite stabilizers on his austenite-ferrite seesaw, austenite will segregate in proportion to the degree of overbalance.

Not to be confused with retained austenite, segregation austenite is like banded delta ferrite in many ways (see Fig. 2). It, too, is formed by chemical segregation during solidification. The first grains to solidify contain less carbon than originally present in the liquid. As these low-carbon grains nucleate and grow, carbon increases in the remaining liquid. The last portion

Fig. 2 — Delta Ferrite, Segregation Austenite, and Ferrite-Free Martensite Are Shown, Left to Right. Delta ferrite cannot be removed by any heat treatment once formed in solidification; segregation austenite can be eliminated by an elaborate heat treatment

to solidify forms high-carbon austenite grains which are stable at temperatures well below −100° F.

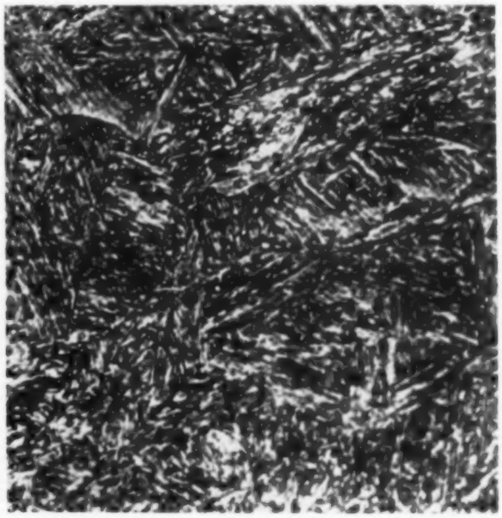
Also, like delta ferrite, segregation austenite does not transform during hot working or heat treatment. Therefore, it also elongates in the direction of reduction. Banded segregation austenite is distinguishable from banded delta ferrite by its lack of clearly defined grain bound-

aries. However, the fabrication characteristics of Type 431 containing banded segregation austenite are similar to those of Type 431 which contains banded delta ferrite. Behavior of fabricated parts is similarly unreliable and failures caused by either phase appear identical.

Removing Segregation Austenite

There is one very important difference between these two second phases. While banded delta ferrite cannot be removed by any known metallurgical process, banded segregation austenite can. Though the principle involved is simple, the eight-step treatment required is somewhat complex. You must:

1. Heat to 2200° F. – to place all carbon in solid solution.



2. Cool slowly to room temperature – to precipitate carbides in grain boundaries.
3. Heat to 2200° F. – to place carbon into solution in adjacent low-carbon grains.
4. Soak at 2200° F. – to diffuse carbon into low-carbon zones.
5. Cool slowly to room temperature – to precipitate carbides in grain boundaries.
6. Heat to 2200° F. – to redissolve carbides.
7. Soak at 2200° F. – to diffuse carbon throughout all grains.
8. Cool slowly – to prevent cracking.

To prevent loss by scaling, heating is in a protective atmosphere.

If the steel were hardened immediately after the above treatment, its microstructure would be 100% martensitic; but its grain size would be larger than A.S.T.M. No. 1. Therefore, an auxiliary treatment to refine the grain is needed. After the last step in homogenization:

1. Heat to 1550° F.
2. Air cool to room temperature.
3. Heat to 1825° F.
4. Air cool to room temperature.
5. Temper 4 hr. at 1200° F.

Ferritte-free Type 431, destabilized and refined as above, is a single-phase wholly martensitic alloy with a grain size of A.S.T.M. No. 3 to 5 after hardening. In the fully hardened and tempered condition, it is more isotropic and ductile than any other conventionally melted steel capable of heat treatment to a similar strength level. Its corrosion resistance and strength at room and elevated temperatures are superior to the same steel containing ferrite. Following are typical tensile properties:

	Longitudinal	Transverse
Ultimate strength	210,000 psi.	210,000
Notched tensile strength	257,000	256,000
0.2% yield strength	154,000	153,000
Elongation in 1 in.	19%	15%
Reduction of area	60%	40%

Machining Characteristics

Ferrite-free steel is difficult to machine when fully hardened. Comparable to the unstabilized 18-8 grades, feeds and speeds normally used in

machining the 18-8 grades are quite satisfactory. Tools must be sharp. Milling, drilling, and tapping are impractical and should be performed before hardening whenever possible.

Because its thermal conductivity is much lower than ordinary alloy steels, Type 431 is highly susceptible to grinding cracks. Similar grinding practices will produce higher thermal gradients than in materials of higher thermal conductivity. Since higher thermal stresses and residual stresses result, special methods must be used when grinding.

Heat Treating Characteristics

The low thermal conductivity must also be considered during heat treatment. Because high thermal stresses are apt to develop during heating and quenching, preheating in the 1200 to 1500° F. range prior to austenitizing is good practice. This is particularly necessary when heating complex parts or those with large cross sections.

To insure complete solution of carbides, parts must be austenitized at 1850 to 1900° F. for 30 min. per in. of cross section. Higher temperatures or longer times will result in grain growth and more austenite retention.

No steel alloy produced today is more susceptible to hydrogen embrittlement. Parts can be catastrophically embrittled by certain "protective" atmospheres. Even after tempering at 550° F., the degree of embrittlement, caused by atmospheres containing CO and H_2O (exothermic and endothermic gas) is proportional to the hydrogen content of the atmosphere. Embrittlement from other atmospheres such as dissociated ammonia and pure hydrogen depends on both the hydrogen and water vapor content of the atmosphere. Heat treatment in wet hydrogen or steam results in parts which are as brittle as glass. The data indicate that austenitizing atmospheres containing only absolutely dry hydrogen should have no embrittling effect. Since commercial drying equipment cannot approach this degree of dryness, to avoid hydrogen embrittlement, *do not heat treat Type 431 in protective atmospheres containing hydrogen.*

Nitrogen Pickup

Other detrimental conditions can occur during austenitizing. Type 431 is an alloy with much chromium; this element, when heated (even though alloyed with other metals and in solid solution), has a high affinity for nitrogen. If hot enough, it will absorb this element from the atmosphere. At 1875° F. the amount which diffuses into the surface layers from air and most commercial atmospheres is of some significance. (This diffusion phenomenon differs from that associated with hydrogen; nitrogen combines with steel and changes its hardenability and transformation characteristics.) Nitrogen absorbed during heat treatment increases the surface hardness slightly. Enough can be picked up from incomplete ammonia dissociation (in dissociated ammonia atmospheres) to stabilize the surface austenite and cause an austenite case to be retained after quenching.

In certain slightly oxidizing atmospheres, ferrite-free Type 431 is susceptible to intergranular oxidation during austenitizing. Oxidation, occurring more rapidly at grain boundaries, produces sharp intergranular stress concentrations which, as Fig. 3 shows, can promote craze cracking during quenching. Premature failure of parts can also result.

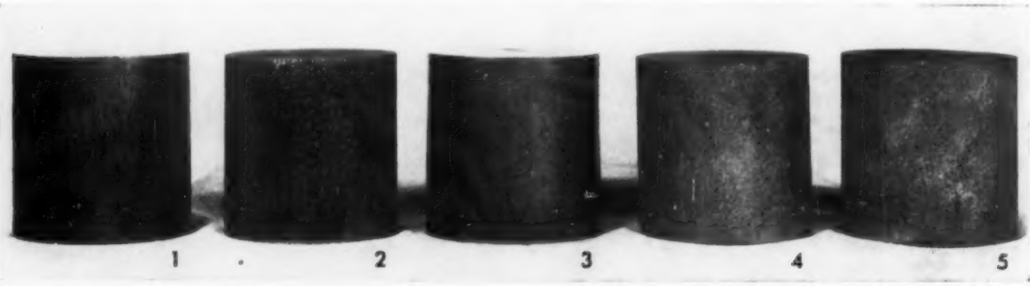


Fig. 3 – Transformation Cracking. All were austenitized at 1875° F. for 1 hr.; atmospheres were air (1 and 2), argon (3 and 4), and rich exothermic gas (5). Specimens 1 and 3 were oil quenched, and the rest were cooled slowly in air. Note that cracking is avoided by austenitizing in a neutral or reducing atmosphere

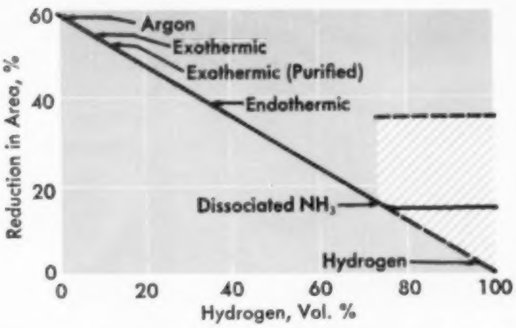


Fig. 4 – Effect of Austenitizing Atmosphere on Ductility. With endothermic and exothermic gases, embrittlement is proportional to the amount of hydrogen; for the other gases, embrittlement depends on both hydrogen and water vapor content

To sum up, during austenitizing, Type 431 can be detrimentally affected by hydrogen, nitrogen, oxygen, water vapor, and carbon monoxide in austenitizing atmospheres. To assure complete freedom from detrimental effects caused by these gases, it should be autenitized only in completely inert atmospheres such as dry argon or dry helium. Use of any other atmosphere represents some compromise in quality and reliability. Figure 4 illustrates the effect of various atmospheres on ductility.

To prevent contamination of surfaces and allow the protective atmosphere to perform its job, parts, heat treat fixtures, and racks which contact the parts must be surgically clean and free from contaminants. Often, just passivating before heat treatment is not enough. Vapor blasting or pickling is better. Racks and heat treating fixtures should be made from an austenitic stainless steel or Inconel. Each part must be racked and supported to allow the atmosphere to circulate freely.

Quenching Procedures

The literature of producers states that Type 431 can be hardened either by oil or air quenching. It is true that full strength will be developed by either quenching procedure. However – and the literature is certainly not adequate on this point – air hardening severely lowers ductility, notch impact strength and corrosion resistance. During slow cooling, carbides precipitate in the austenite grain boundaries at the same temperatures and in the same manner as in unstabilized 18-8 stainless grades. The resultant structure is brittle and susceptible to intergranular corrosion and catastrophic stress-corrosion cracking. Therefore, for optimum mechanical properties and corrosion resistance, rapid quenching is necessary.

The M_s of ferrite-free Type 431 is quite low. Depending upon the analysis balance, it may be as low as 240° F. Since transformation is not complete at 150° F. or even at room temperature (there may be 20% retained austenite), complete transformation is assured only by cooling parts to at least −90° F. during quenching. With a deep-freeze treatment incorporated in the quenching operation, parts will contain less than 2% retained austenite.

Mentioned previously (in connection with grinding and austenitizing) was the low thermal conductivity which causes high thermal gradients to be developed during rapid heating and cooling. As a result, this steel is prone to quench cracking. To minimize this, rough machine parts as closely as possible to finished size prior to heat treatment, provide generous radii in parts to be hardened and marquench* into salt at 350 to 500° F. The isothermal transformation characteristics of Type 431 are ideally suited to marquenching procedures since mixed structures are not produced. Mechanical properties and corrosion resistance remain constant.

Like the rest of the 400 series, Type 431 should never be tempered between 700 and 1100° F. In this range, tempering results in low ductility and susceptibility to intergranular corrosion. Providing parts are processed as outlined above, tempering for 3 hr. at 500° F. will produce parts immune to stress-corrosion cracking in sodium chloride and sea water solutions. Recent stress-corrosion tests in stronger corrodents indicate that double tempering and marquenching provide even further immunity.

In general, corrosion resistance is proportional to smoothness and brightness of the surface. Parts which are machined to at least rms. 63 on all surfaces and passivated have excellent corrosion resistance in marine atmospheres. Electropolished parts are even better.

There you have it. Type 431 stainless steel seems barely producible, barely machinable and barely heat treatable. There is no steel more expensive to fabricate, or more prone to hydrogen embrittlement, quench cracking, thermal or residual stresses. Though very reliable when melted and processed correctly, extreme care is essential in all operations.

*Deep freezing is also required when marquenching. Cooling should not be interrupted after parts are removed from salt.

The Gradient Furnace – a Versatile Research Tool

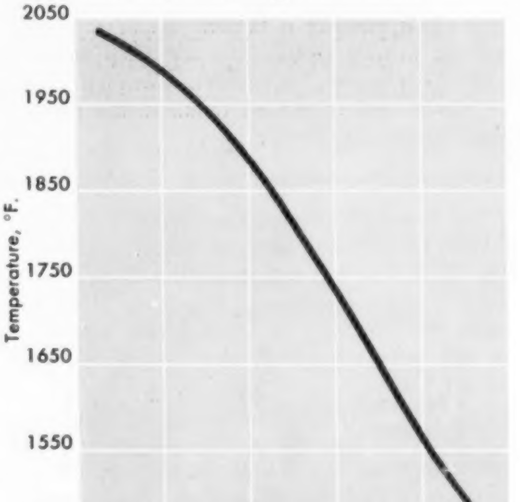
By ANDREW FEDUSKA
and PAUL E. BUSBY*

A furnace muffle heated at only one end will have a range (or gradient) of temperature along its axis. With proper experimental techniques, such a furnace shortens considerably the time normally necessary to determine grain coarsening, austenitizing and tempering temperatures. It can also be used for isothermal transformation, solution treating and aging studies. (J-general, W27j; ST)

A SMALL CHAMBER heated at one end and open to the room at the other comprises the heart of the gradient furnace. This simple arrangement, when operating, provides a range of temperatures along the muffle. As described 13 years ago, by J. W. Halley†, who used it to determine grain coarsening characteristics of steels, it provided a 1300 to 2100° F. gradient. With it, grain sizes for a range of temperatures could be determined on a single specimen in one test. Obviously, this was quite an improvement on traditional methods.

Impressed by its rapidity in determining grain coarsening temperatures, we at the Heppenstall laboratory decided to build a gradient furnace of our own based on Halley's specifications. As

Fig. 1 – Curve Representing Typical Grain Coarsening Test Gradient



*This work was done by the authors when they were associated with the Heppenstall Co., Pittsburgh, as research associate and director of research, respectively. The authors wish to acknowledge the assistance of R. B. Corbett, L. R. Cooper, L. MacNaughton, R. E. Kelly, and R. A. Lange of the Heppenstall Co.

†*Metals Technology*, June 1946.

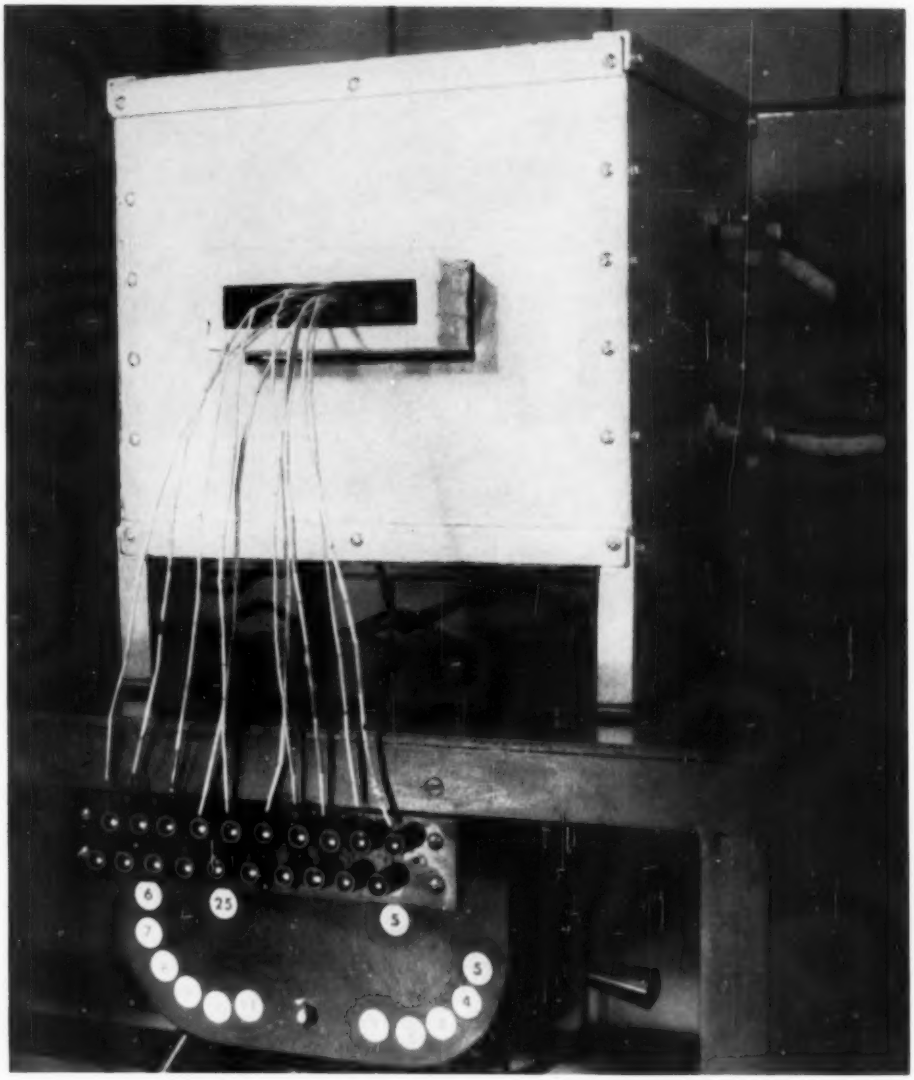


Fig. 2 – Gradient Furnace With Thermocouples Extending From Calibration Bar to Terminals. Experiments start after furnace gradient has stabilized

shown in Fig. 2, this furnace is heated by two Globar elements. Power is obtained through a step transformer from a 220-v. source, and temperature is maintained by a suitable controller. A stainless steel muffle, constructed from welded ½-in. plate, projects through the front and dissipates heat to obtain a gradient from the hot backwall to the cooler front end. A second furnace was later constructed with four Globar elements to provide higher temperatures and faster heating of larger samples.*

While Halley determined the gradient with thermocouples spaced at ½-in. intervals in a standard test bar, we use only one thermocouple supported so that it can be conveniently located at desired points. With either method, temperatures can be read at various positions (after allowing time for equalization) to check the gradient while specimens are in the furnace.

*The Arcweld Mfg. Co. has recently marketed a gradient furnace, the design of which is based on experiences encountered during the operation of these furnaces. It was shown for the first time at the 1958 National Metal Exposition in Cleveland.

To start operation, the furnace backwall is heated to the desired control temperature. After equilibrium is reached, the gradient is determined. It should be checked several times to assure that stability has been established.

The specimen consists of a notched bar which may be fractured lengthwise after quenching from the gradient furnace. From such fractured bars fracture grain size rating can be obtained. Figure 1 on p. 92 illustrates a typical grain-size determination gradient. Grain coarsening temperatures are easily ascertained by matching the bar to a gradient drawn to size. If necessary, the remaining half of the bar can be polished (in its entirety or cut into convenient lengths) for more detailed microscopic study.

Austenitizing Conditions

It is at once apparent that the gradient of Fig. 1 will include critical temperatures of a number of steels. With the conversion of ferrite to austenite there is an abrupt change in grain size, and examination of the fractured bar reveals such a change where the temperature is too low to form austenite. Obviously, the corresponding temperature must be the approximate critical temperature.

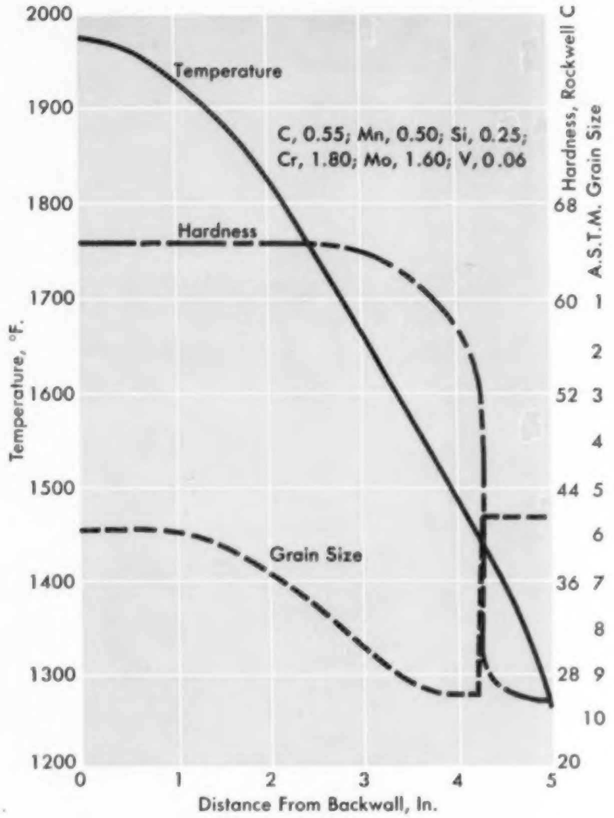


Fig. 3 — Hardness, Grain Size and Temperature Along Test Bar. Critical temperature is 1450° F.; full hardening is attained at 1675° F.

Hardness determinations along the as-quenched gradient test bar will indicate the austenitizing temperature required to provide maximum hardness. Metallographic examination also provides a measure of the degree of carbide solubility. Therefore, with one experiment, the influence of austenitizing temperature on a number of metallurgical variables becomes readily available. The curves of Fig. 3 indicate that the steel is best austenitized at 1675° F. where the as-quenched hardness is Rockwell C-64 and the austenite grain size is No. 8. For annealing treatments, 1500° F. would be selected from the temperature curve.

Tempering Studies

Now that the austenitizing temperature is known, the metallurgist becomes logically interested in the tempering temperature. To obtain this, the gradient furnace controller is adjusted to provide a backwall temperature approximating the maximum tempering temperature desired.* A sample previously quenched from the selected austenitizing temperature is then tempered in the gradient furnace for the desired time. The tempering curve of Fig. 4 can be plotted from the temperature gradient and the hardness determined along the bar. Obviously, if the influence of tempering time is also desired, a group of quenched bars may be inserted into the furnace simultaneously, and removed individually at selected time intervals.

The gradient furnace is also useful for approxi-

*It should be emphasized that the gradient temperature range attained is determined by the furnace design (dimensions of muffle), the selected backwall temperature and the room temperature. As a result, the magnitude of the temperature gradient decreases as the backwall or control temperature decreases; for the 5-in. bar used in our furnace, typical temperature ranges are 2050 to 1450° F. when the control temperature is 2050° F., and 1350 to 850° F. when the control temperature is 1350° F.

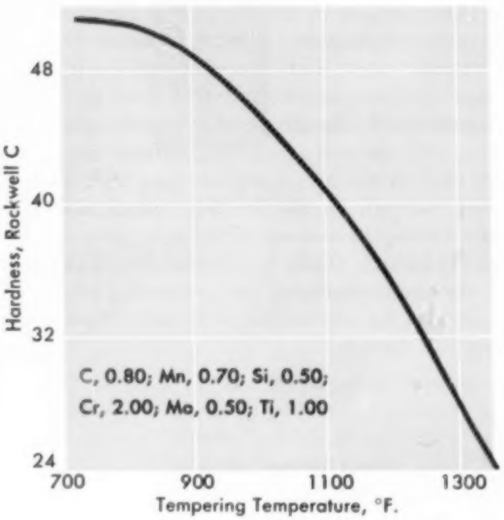
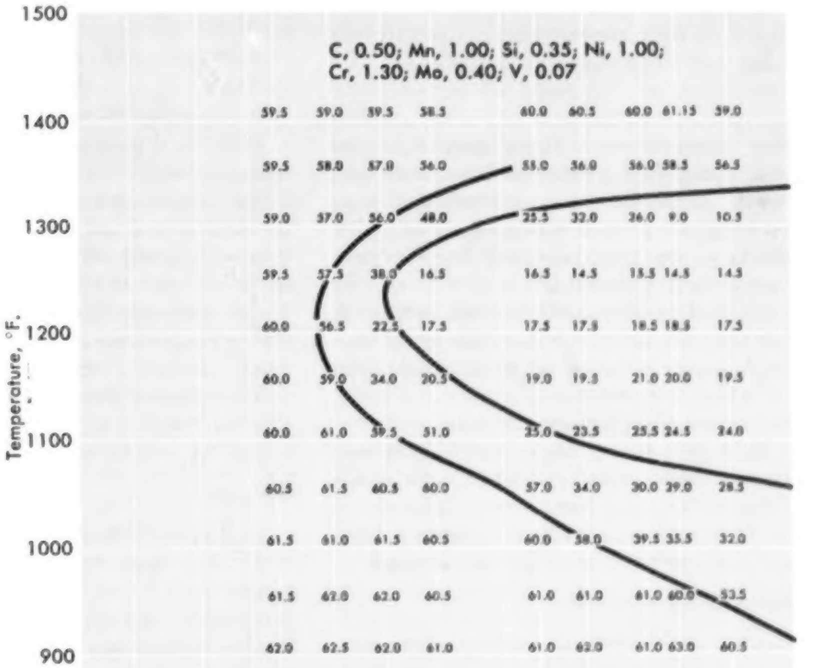


Fig. 4 – Tempering Curve for Steel. Bar was austenitized at 1575° F. and oil quenched before tempering for 2 hr.

mating TTT-diagrams for certain alloy steels. Bars are austenitized in a muffle furnace, and then placed in the gradient furnace to be held "isothermally" for varying times. Water quenching follows. Transformation may be determined metallographically, or may be crudely estimated from hardness measurements (see Fig. 5). In this manner, a range of isothermal transformation temperatures may be studied in one sample for a particular transformation time.

It should be mentioned that isothermal transformation studies can be made only on fairly sluggish steels. Depending on the austenitizing temperature and the number of samples in the gradient furnace, the time required for the specimens to adjust to the gradient temperatures may approach ½ hr. Thus a significant error can be present in the determined reaction start times for steels of relatively low hardenability. Some precooling in air may be done to hurry the cooling rate, but the specimen should not be per-

Fig. 5 – Partial TTT-Diagram as Determined by Hardness Measurements. Bars are austenitized and transferred to gradient furnace for varying times



mitted to cool below the highest isothermal transformation temperature of interest.

In addition, it is not known what effect interaction of transformation products along the bar may have on the adjacent material. For example, transformation at the nose of a TTT-diagram may possibly interact to cause more rapid transformation at temperatures just above or just below the nose.

Aging Studies

The gradient furnace is also useful for aging studies. Bars may be solution treated in the gradient furnace to obtain a range of solution treating temperatures. These bars are then checked along their lengths for solution treated hardness. Later, the bars are aged at one selected temperature and water quenched, after which they are again checked for hardness. The aging treatment and hardness tests may be repeated in time increments as often as desired, so that complete aging curves at one aging temperature can be obtained for innumerable solution treating temperatures.

To determine the influence of aging temperature, bars may be solution treated from one selected temperature and then aged in the gradient furnace, the aging temperatures being determined by the furnace gradient. Figure 6 illustrates aging curves obtained by this method.

Combined Heat Treatments

Many of the individual gradient treatments described thus far may be combined advantageously in the gradient furnace. For example, the effects of both solution treating temperature and aging temperature on hardness can be determined. A slab specimen, approximately $5 \times 5 \times \frac{1}{2}$ in., is first solution treated in the gradient furnace at 2100 to 1450° F., and cooled to room temperature. It is then rotated 90° in a horizontal plane, and reinserted into the furnace (now operating at 1300 to 800° F.) for the aging treatment. With all possible combinations of these solution and aging temperatures thus represented in the specimen, hardness tests at desired intervals on the 5×5-in. dimension provide a complete account of the aging response of the material. Similarly, the combined effects of various austenitizing and tempering temperatures may be determined with one furnace and one slab specimen.

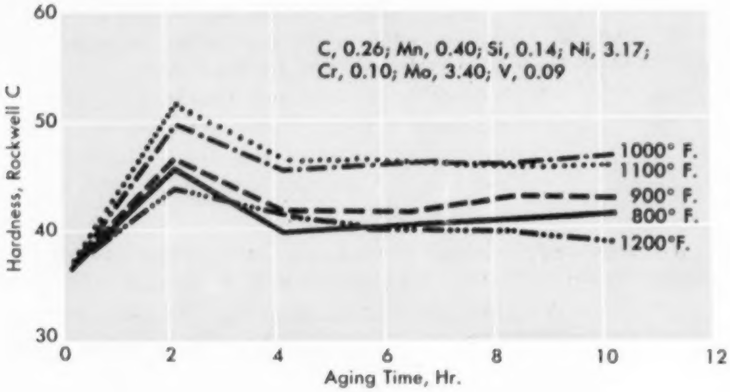


Fig. 6 – Solution Treated Steel Aged in Gradient Furnace

With two gradient furnaces available, one operating in the austenitizing range and the other in the isothermal reaction range, hardness tests on each of a series of slabs, which have been gradient austenitized, rotated 90°, gradient reacted for various times and quenched, provide a good approximation of the influence of austenitizing temperature on transformation characteristics. However, because of the large sample size and consequent slower cooling rate to the isothermal reaction temperature range, this technique can only be used for very sluggish steels.

Summary

The primary advantage of the gradient furnace is the short time required to investigate experimental steels for which no heat treat information is available. All the information needed to heat treat a steel can readily be obtained with a few experiments. In addition to the studies described, the gradient furnace may be profitably applied for the ready solution of any specific heat treating problem in which temperature is an important variable.

Staff Report

New Uses for Powder Metallurgy

A method for continuous compaction opens up new possibilities for using powders to produce bar and sheet products and to fabricate bimetal combinations. Metal powders are mixed with other materials to give compositions for special uses in nuclear and other applications. These were among developments revealed at the annual meeting of the Metal Powder Industries Federation. (H-general)

THE PHOTO in Fig. 1 illustrates a method for continuous compaction of ceramic and metal powders into bars of unlimited length and large cross-sectional area. The process was described by F. Emley of the materials engineering department, Westinghouse Electric Corp., at the annual meeting of the Metal Powder Industries Federation in Detroit.

The method, according to Mr. Emley, offers an economical way to produce specialty metals and alloys, compared with other ways of fabrication. Available equipment, such as reciprocating-type presses, can be easily modified for small-scale production of bars from powder, granular or sponge raw materials. An automatic operation can be designed for large-scale work. The developers of the process (C. Deibel, also of Westinghouse, was co-author of the paper) predict that in the future the compaction process will provide a basis for economical, large-scale production of common metals and alloys in bar, sheet and strip, directly from powders.

How the Process Works

Referring to the cutaway sketch in Fig. 1, loose powder marked A is placed into a three-sided trough with sides marked B and a bottom marked C. The powder is compressed with a punch marked D, which consists of a flat pressing surface parallel to the powder surface and also a pressing surface which is angled to the powder surface. In operation, the punch is raised clear of the pressing area and loose powder is charged into the channel formed by the die walls. (A starting block is used to contain the loose powder fill until pressing is underway.) The punch is lowered into the channel; the horizontal flat surface, called the finishing area, is adjacent to the starting block.

Continuous Process – The powder moves as a unit, and pressure strokes operating over the length of the sloping portion of the punch cause the powder to be pressed with an infinite number of pressure values from zero, at the furthermost section of the angled surface, to maximum pressure under the finishing area at the opposite end of the punch. By repetition of this cycle, loose powder is pressed into a continuous bar.

The slope of the punch is not critical; it may vary over a wide range of angles from the horizontal. Low angles reduce the speed and efficiency of the process but may be desirable for pressing a small powder fill. High angles cause excessive quantities of powder to be laterally displaced, resulting in variations in bar thickness. A proper balance must be established depending upon use requirements.

Properties of Compacts

Mr. Emley reported that copper powder pressed with a ram load of 60 tons, then sintered for 1 hr. at 1000° C., gave a good bar of 90%

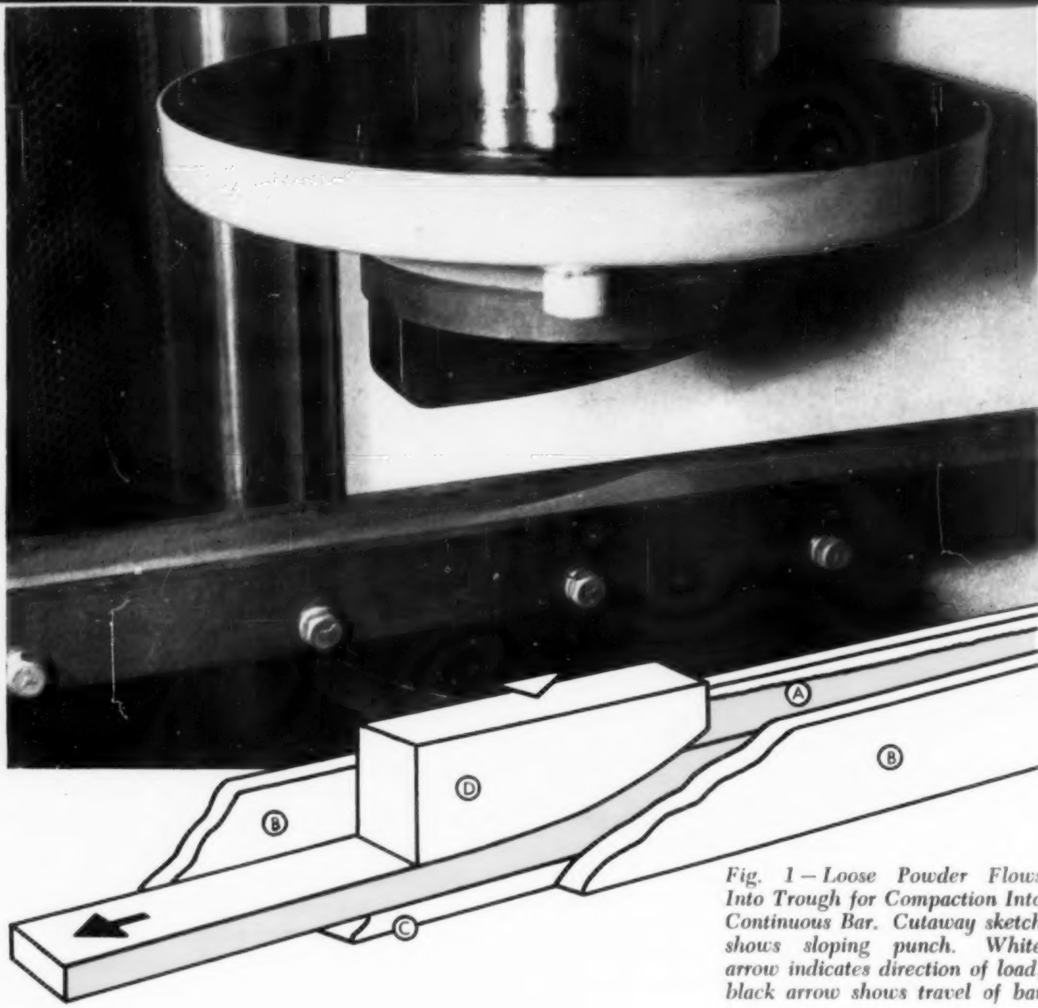


Fig. 1 – Loose Powder Flows Into Trough for Compaction Into Continuous Bar. Cutaway sketch shows sloping punch. White arrow indicates direction of load; black arrow shows travel of bar

density. Bars have been produced from commercial iron powders including electrolytic, RZ and Swedish sponge iron. A variety of alloys have been produced from elemental powder mixes. These include iron-nickel magnetic alloys, iron-silicon alloys and Kovar alloy (an iron-nickel-cobalt glass-sealing alloy). The process has been used to press melting stock into electrodes for consumable arc melting utilizing titanium sponge, sponge iron melting stock, columbium roundels and tungsten and molybdenum powders.

Possibilities for Cladding – The bar shown in Fig. 2 is copper clad with iron, illustrating an interesting variation of the process. It was made with one end entirely of iron and a copper center starting at some point near the middle and continuing through the bar. The photograph illustrates the uniformity of wall thickness.

Some of the potential applications for continuous compaction visualized by Westinghouse people are given below:

- Fabrication of large sizes of sheet, strip and bar from molybdenum, tungsten, tantalum and other refractory metals.
- Continuous process for fabrication of tungsten filaments from powder.
- Production of sheet and strip alloys where precise control of composition is essential for special properties.
- Fabrication of metals, such as beryllium, which are too brittle in form of large ingots to be processed by casting or conventional techniques.
- Production of ceramic bars.
- Use of powder to manufacture nuclear reactor components such as control rods and fuel elements. These may include metal, ceramic or cermet compositions.
- Single-step preparation of clad bars or strip including bimetal bearings and thermal bimetals.

Uses for Lead Powders

Thin lead sheets can be made from lead powder which have double the tensile strength of similar sheet produced by casting and rolling, according to R. L. Ziegfeld, secretary-treasurer

of the Lead Industries Assoc., who told M.P.I. about new applications for lead powders. He pointed out, also, that preliminary tests indicate that the strength of sheet produced from powder is retained at higher temperatures than for ordinary lead.

Lead powder is being mixed with polyethylene to produce molded mechanical parts. One example is a small flywheel for a tape recorder. Lead adds the necessary mass; the combination gives a material which is easy to mold, and parts have the hardness and mechanical strength needed. Lead powder mixed with epon resin is used to bond metals and other materials. It is also suitable for repairing lead under corrosive conditions.

Nuclear Shields – Many mixtures similar to the above are being used in nuclear radiation shielding. A mixture of lead powder and paraffin, which can be molded, is useful for complex shields. While the lead serves to shield gamma rays, the binder, containing hydrogen, is a neutron shield.

Certain other applications take advantage of lead's superconductivity. Compressed lead powder is used to make superconducting connections between thin films of vapor-deposited metals and external circuits in computers and counters.

Bonding Carbide to Steel

Jerome F. Kuzmick and Glenn B. Goodfellow of Powder Alloys Corp. described a method which gives improved joint strength in bonding carbide tips to steel shanks. The bonding material, called "Plymet", is produced in the form of thin wafers which are molded from a nickel-iron metal powder and sintered at low temperature. High-temperature brazing or welding flux is generally mixed with the metal powder prior to molding, or wafers may be flux impregnated after molding. This makes the wafer "self-fluxing" in the bonding operation.

A wafer slightly larger than the carbide tip is placed between the carbide and the steel shank. About 500 psi. pressure is applied to the assembly while it is heated at 1900 to 2000° F. for about 1 min. Unlike brazing, Plymet does not melt during the bonding operation. Joints have a rupture strength over 100,000 psi., it was reported. When carbide is bonded to air hardening or high speed steel, tools can be heat treated without damage to the joint or carbide. The process has been applied to carbide-tipped core rods for powder metallurgy and is being investigated for blanking punches and dies and other tipped tools.

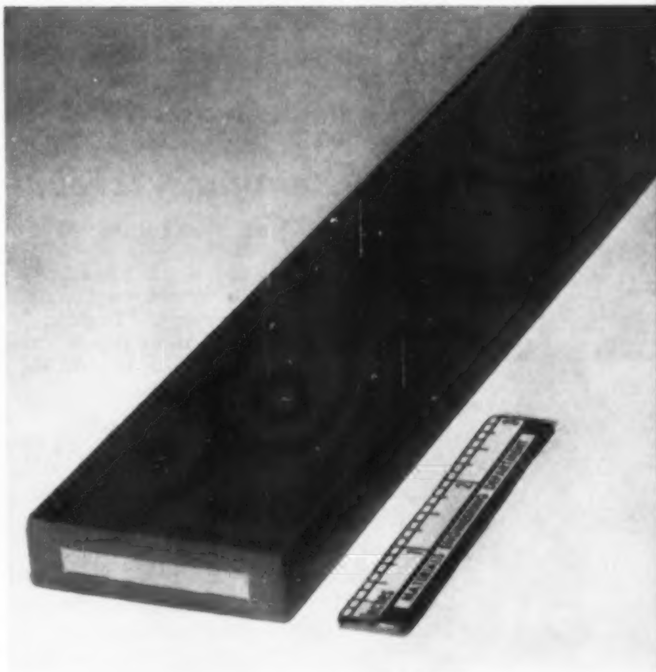


Fig. 2 – Copper Bar Clad With Iron by Continuous Compaction Process

From Here and There

• J. D. Shaw of S-K-C Research Associates discussed aluminum powder metallurgy and showed samples of strip produced from aluminum powder.

• Bennett Bovarnick, chief of the sintered metals and ceramics branch of Watertown Arsenal, presented data to show that it may be possible to employ electrochemical potential measurements as a nondestructive test to indicate extent of sintering and measure strength of powder metallurgy parts.

• John Haertlein of Metals Disintegrating Co. told how his company is using micromesh sieves to extend the range of sieving equipment to particle size measurements down to 20 microns. Micromesh sieves are made by electroforming nickel on master grids and are now available commercially. They consist of precise square holes which permit accuracy of measurement heretofore unobtainable.

• George A. Roberts, vice president, technology, of Vanadium Alloys Steel Co., was re-elected president of M.P.I.

Book Review

Powder Metallurgy Techniques for Reactor Designers

*Reviewed by CARL A. LIEDHOLM**

POWDER METALLURGY IN NUCLEAR ENGINEERING. Proceedings of Conference on Powder Metallurgy in Atomic Energy. Organized by Henry H. Hausner, American Society for Metals, Cleveland, 1958. 275 p. $8.50.

PROBABLY NO MAN'S EXPERIENCE will ever cover the entire range of this book on various applications of powder metallurgy to reactor construction. It is written by 20 authorities and experts, headed by Henry H. Hausner.

Its 15 chapters, covering 260 pages, begin with an introduction to the general metallurgical problems in the design of nuclear reactors. This chapter is an inclusive but highly condensed review of the basic material problems associated with the reactor core. It ranges from discussion of the general physical, mechanical and nuclear property requirements, corrosion limitations and radiation damage to the problems of the fuel matrix, moderator and control component.

From this brief resume of the general requirements which often can be met most satisfactorily by powder metallurgical techniques, the book delves into specific problems, methods, capabilities and hazards of powder metallurgical technology. Chapter II, "Factors Affecting Sintering", makes the practical reader aware of the various mechanisms which are thought to control the over-all process. The examination of this theoretical background, with its accompanying experimental data, should improve the practical reader's "feel" for the important variables which control sintering.

The third chapter will especially interest those engaged in the somewhat hazardous preparation of powders of uranium and thorium. It is followed by descriptions of the powder metallurgy of the exotic, low cross-section metals zirconium and beryllium, and the fuel materials uranium and thorium.

In later chapters one learns about the potentials of powder metallurgy in the preparation of metal alloys and an application to the study of Zr-Be phase diagram. The reader is then introduced to new or recent powder metallurgical techniques whose applications to reactor components and accessories are discussed and evaluated. This chapter is a balanced presentation of stimulating potentials and sobering limitations. It might help promote mutual understanding between the designers who dream in ivory towers about the facile creation of new super materials and the practical fellows who struggle in the valley below with recurring fabrication problems.

A specially spirited chapter is devoted to metal-powder rolling, an idea originated over 50 years ago but only explored thoroughly and developed during World War II by the Germans. Important nuclear applications are predicted.

Two chapters on ceramic fabrication are included in the book because of the close relation between the production methods and some applications of powder metallurgy and ceramics. A separate chapter is devoted to cermets.

The chapter on ceramic fuel materials includes moderator materials such as BeO and low cross-section, potential matrix materials such as MgO, ZrO_2 and others, in addition to the fuel materials proper, such as UO_2 and ThO_2. It contains several property tables useful to designers and materials men. The various standard compacting methods are thoroughly described.

An instructive and timely discussion of dispersion-type fuels completes the chapters on powder technology.

The final chapter discusses hazards involved in handling pyrophoric or poisonous powders. To give an idea of these dangers, the permissible level of air contamination for beryllium is 2 micrograms per cu.m. and for plutonium 0.0001 microgram.

The book is a valuable textbook and reference source and is recommended to all practical reactor materials men. It gives an impressive picture of the volume and scope of research done on exotic powder materials and the ingenuity of the men who are working in this field.

*Chief, Metallurgical Division, Nuclear Power Dept., Curtiss-Wright Corp., Quehanna, Pa.

A Report From the U.S.S.R.

A Look at Russian Steels

*By ARTHUR B. TESMEN**

As with engineers in the United States, Russian metals engineers have a long list of steels with varying properties and compositions to choose from. These include carbon, alloy, stainless and toolsteel grades. Heavy stress is laid on the development of new steels. (S22; ST)

By 1965, when the new seven-year plan for industrial development of the U.S.S.R. is completed, pig iron production will have risen from 45 million to 77 million tons, and steel production from 56 to 96 million tons, according to Russian reports. Increases are also scheduled in oil (from 130 to 265 million tons), in coal (from 540 to 600 million tons), in chemicals (three-fold), and in electrical energy (two-fold). To support these ambitious goals, production of machines is expected to be nearly doubled. This will include increases in forging equipment (1.5 times), rolling mills (2 to 2.2 times), and power turbines (2.8 times).

In metalworking, priority is given to the modernization and mechanization of press-forge and casting equipment. Also on the high-priority list is installation of 1300 automatic metalworking production lines, development of automatic programed machine tools, metal forming and coining presses, and machines for producing high-strength castings under pressure. Furthermore, this elaborate plan includes design and construction of up to 80 large specialized casting, forging, and forming plants incorporating latest features for eliminating manual work.

Metallurgists Are Important

Soviet metallurgists are expected to play an important role in these developments. Some of their future problems concern recent decisions to increase the production of powerful steam turbines and pressure vessels. Operating in the 1100 to 1300° F. range and up to 4400 psi., these machines will require new heat resistant alloys. The Russians appear quite advanced in this field, as well as in evaluating new heat treating methods for improving properties of known alloys. In their comprehensive approach to research, they study theory of heat resistant alloys, principles of alloying, and maintenance of stable structures and properties at elevated temperatures. Mutual influence of carbides and intermetallic compounds, effect of melting and heat treating upon heat resistant properties of large forgings and castings, and weldability also receive their attention. A long list of steels, almost as diverse in properties and application as our A.I.S.I. group, has resulted.

Pearlitic and Martensitic Steels

Among the practical results of this research was the development of Cr-Mo-V pearlitic steel for reinforcing members of steam turbines operating at 1000° F. A number of compositions were investigated to develop optimum strength, ductility, and stress relaxation at this temperature, and a steel containing 0.25 C, 0.7 Mn, 2.3 Cr, 1.0 Mo and 0.4 V was selected. A similar

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casting composition with matching welding electrodes is used for intricate parts with lower ductility levels.

Nickel is a critical element in the Soviet Union and steels containing it are replaced, wherever possible, by stainless steels containing 11 to 13% Cr and pearlitic steels with up to 4% alloying elements. These are suitable for the 1000 to 1100° F. range.

Since heat resistance of martensitic stainless steels (for turbine rotors, vanes, bolts, and other vital parts) is enhanced by molybdenum, vanadium, and tungsten additions, the steels shown in Table I were selected for these applications. For the first three, the best combination of properties occurred when they contained 10 to 20% ferrite. Furthermore, the combination of tungsten and molybdenum produces maximum corrosion resistance. Steel 15X12MФ is used for first-stage vanes of high-temperature high-pressure steam turbines.

The last two steels listed in Table I approach austenitic material with respect to heat resistance. Further, they cost less since they use more abundant tungsten instead of critical nickel. Casting alloys similar to those shown in Table I, but with higher carbon content, have also been developed.

Investigations of Cr-Mo-V, Cr-Mo-W and Cr-W-V steels containing up to 3 to 4% alloying elements (generally, 0.25 C, 1.5 Cr and 0.25 V) revealed a relationship between creep resistance and the total molybdenum and tungsten content. When normalized and tempered, steels containing 0.5 at.% molybdenum and tungsten have maximum creep resistance.

Pearlitic steels attain heat resistance through alloying with several components. Consequently, several steels containing 0.10 to 0.30 C, 1.5 to 2.0 Cr, 0.20 to 0.40 V, 1.0 to 1.4 Mn, 1.0 to 1.4 Si, and varying amounts of molybdenum, tungsten and copper (to make up the 3 to 4% alloy content) were developed. Vacuum degassing units are used in casting some large ingots (see typical unit in Fig. 1).

Table I – Martensitic Stainless Steels

Designation	C	Si	Mn	Cr	Ni	W	Mo	V
15X12MФ	0.15	0.25	0.70	12.0	0.22	—	0.70	0.30
15X12BMФ	0.15	0.22	0.64	12.5	0.20	0.85	0.46	0.20
15X12B1MФБТ*	0.15	0.30	0.30	11.50	1.08	0.63	0.50	0.37
1X12BMФ	0.13	0.25	0.70	11.5	—	2.0	0.70	0.25
1X12B4MФ	0.13	0.25	0.70	11.5	—	4.0	0.70	0.25

*Also contains 0.23% Cb and 0.14% Ti.

Austenitic Steels

In the austenitic field, a new weldable steel containing 0.16 C, 0.55 Si, 0.70 Mn, 15 Cr, 15 Ni, 3 Co, 2 Mo, 1 W and 0.25 Ti has been developed for large, complex steam and gas turbine castings operating up to 1200° F. Other cast austenitic grades containing over 1% Mn and Si, and 0.50% Cu, together with the usual amounts of chromium and nickel, have been used for turbine blades overlayed with sheets of 18-9 Cr-Ni steel. A 16 Cr, 13 Ni, 2 Mo, 1 Cb austenitic steel has been used for first-stage turbines, welded steam valve bodies, and large rotor weldments up to 40 in. diameter and 17 ft. long. For the 1000 to 1200° F. range, high-pressure steam piping has been made from an austenitic steel containing 0.10 C, 0.65 Si, 1.00 Mn, 18.0 Cr, 12.0 Ni and 0.50 Ti. This steel is stable upon aging at 1300° F. for 10,000 hr. and at 1400° F. for 3000 hr. It also has good weldability.

An austenitic steel with 0.25 C, 18 Cr, 8 Ni and 2 W combines excellent corrosion with wear resistance after nitriding. With a ductile core, and uniform hardness gradient from case to core, this steel attains a case depth of 0.007 in. in 40 hr. of nitriding.

Future improvements in heat resistant steels will be sought through vacuum melting and degassing, cleaner raw materials, rare earth modifications, and ultrasonic vibration. Pearlitic and semiferritic steels for service at 1075 to 1300° F., austenitic grades with a minimum of nickel and molybdenum for service at 1475° F., and corrosion resistant materials for stationary gas turbines operating at 1400 to 1475° F. will have to be developed, as well as methods of casting and forging these alloys.

Low-Alloy Constructional Steels

High-strength constructional steels, similar to our Corten, Mayari, and others, are widely used. Some are listed in Table II.

Steel 14XГC is used for large-diameter welded gas pipe, and CXЛ3 for rivets. Steel MK when used in the construction of the Kiev-Moscow pipeline resulted in a weight saving of 44,000 tons. The wall thickness of the 20.6-in. diameter pipe could be decreased from 0.47 to 0.31 in. The grade is supplied, normalized and tempered, in 0.158 to 1.24-in. thicknesses to the minimum specification of 50,000 psi. yield, 70,000

Table II – Low-Alloy Constructional Steels

Grade	C	Mn	Si	Cr	Ni	Cu
14ХГС	0.11-0.16	1.0-1.3	0.4 -0.7	0.5-0.8	0.3 max.	0.3 max.
СХЛ2	0.12-0.22	0.5-0.8	0.3 -0.5	0.4-0.8	0.3-0.7	0.3 -0.5
СХЛ3	0.15 max.	0.5-0.8	0.3 -0.5	0.4-0.8	0.3-0.7	0.3 -0.5
СХЛФ	0.12 max.	0.5-0.8	0.15-0.30	0.4-0.8	0.3-0.7	0.3- 0.5
ДС	0.12-0.22	0.7-1.1	0.25-0.40	0.4-0.6	—	0.4 -0.7
МК	0.10-0.14	1.3-1.7	0.8 -1.2	0.2-0.4	0.2-0.5	0.15-0.30

Table III – Chromium-Manganese Steels

Grade	C	Mn	Si	Cr
20ХГ	0.15-0.25	0.90-1.20	0.17-0.37	0.90-1.20
15ХГ	0.10-0.20	1.10-1.40	0.15-0.30	0.40-0.60
35ХГ2	0.30-0.40	1.60-1.90	0.15-0.30	0.40-0.70
40Х2Г	0.35-0.42	0.70-1.00	0.15-0.30	1.20-1.50
35Х2ГМ*	0.30-0.40	1.10-1.40	0.15-0.30	1.80-2.20

*Also contains 0.40 to 0.60% Mo.

psi. ultimate tensile strength, and 18% elongation.

Two ultra-high-strength, high-impact resistant steels have been developed for machinery applications. One containing 0.37 C, 0.25 Si, 1.25 Mn, 1 Cr, 1.6 Ni and 0.5 W is heat treatable to 245,000 psi. yield and 300,000 ultimate tensile strength; the other, with 0.45 C, 0.50 Mn, 1.0 Si, 1.3 Cr, 2.3 Ni and 2.0 W, has 275,000 psi. yield and 320,000 tensile strength.

A study was made of failures in steam turbines built of pearlitic alloy steel with 0.20 C, 2.3 Cr, 1 Mo and 0.50 V. Up to 750° F., failures were due to fatigue, while above this, corrosion was responsible. Cold working by rolling increased the fatigue limit effectively.

Since Russians regard nickel and molybdenum as critical elements, they devote a lot of effort to finding adequate substitutes. Manganese is being used increasingly as an alloying element in constructional steels and in medium-carbon steels combined with chromium. Some of Russian Cr-Mn steels are given in Table III.

Steel 15ХГ is a carburizing grade, 35ХГ2 is used in forgings and track link castings, and 35Х2ГМ for high-strength bolts, propeller screws, and high-strength fittings.

Russian investigators use silicon for its effect in increasing the amount of retained austenite upon isothermal transformation (just above the M_s point). The retained austenite is stable during subsequent cooling and helps to improve mechanical properties.

Boron Steels Are Useful

Soviet work in boron steels largely parallels developments in this country. Numerous studies have determined the influence of boron additions upon the properties and hardenability of constructional steels, as well as its influence upon kinetics of austenitic grain growth. Russians theorize, as do some of our investigators, that boron hardens through being absorbed in small amounts at the austenite grain boundaries. This decreases grain-boundary surface energy, and consequently weakens the tendency of the austenite to transform and agglomerate. Future research will attempt to prove this by employing radioactive isotopes and electron microscopy in addition to conventional hardenability tests. Spectrographic methods determine boron contents down to 0.0005.

Adding boron to ЭИ437 (20 Cr, 2.5 Ti, 0.70 Al, 0.05 C, bal. Ni) raised its transition temperature 200 to 300° F. A 0.001% boron addition to medium-carbon low-alloy steel (0.38 C, 1 Cr, 20 Ni) produced sufficient hardenability and

Fig. 1 – Vacuum Degassing Unit for Large Forging Ingots

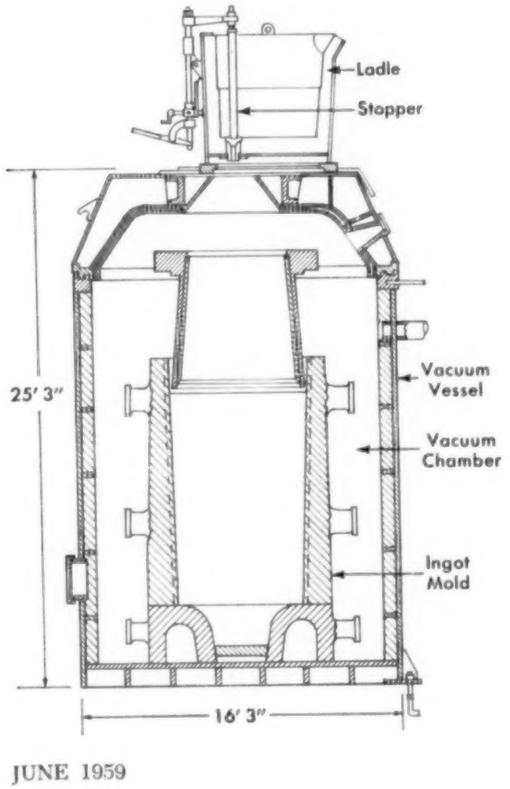

Table IV – Low-Alloy High Speed Steels Before World War II

Grade	C	Cr	W	Mo	V	Si
		High-Chromium Steels				
ЭИ116	.075-0.85	9.5-10.8	—	—	1-1.35	1.5-1.8
ЭИ172	1-1.15	11-13	—	—	2-2.6	1-1.6
ЭИ184	0.80-1.0	7-9	3.5-4.8	—	1-1.5	0.65 max.
		Complex Alloy Steels				
ЭИ276	1-1.15	3.8- 4.6	2.2-2.9	2.3-2.9	2.2-2.8	0.40 max.
ЭИ284	0.9-1.1	4-5	3-3.7	3.7-4.5	2-2.6	0.40 max.
ЭИ290	0.85-1.0	3.6-4.3	2.6-3.9	2.6-3.9	1.5-2.0	0.40 max.
		Medium-Tungsten Steels				
ЭИ262	0.85-0.95	4-4.6	8.5-10	—	2-2.6	0.40 max.

Table V – High Speed Toolsteels

Grade	C	W	Cr	V	Mo	Co
New High-Vanadium and Cobalt Steels						
18-4-2	0.90	18	4	2	—	—
P9K5	0.90	9	4	2.3	—	5
3-5	1.30	3.60	4.4	4.0	3.0	5
13-5	1.35	12	5	5	1.0	5.3
13-5-Cb*	1.50	11.5	4	4.5	1.0	5.7
P10Ф	0.90	10	4	4.2	—	—
P10Ф5	1.25	10	4	4.2	—	—
		Standard Cobalt Steels				
PK5	0.75	18	4	1.2	—	5
PK10	0.8	18	4	1.5	—	10

*Contains 1% Cb.

mechanical properties in 8-in. diameter turbine drill shafts.

Ores from the Kerch region, which are used by Soviet steel mills in the south of European Russia, contain arsenic. The Azovstal Works established that arsenic in amounts above 0.20% has a detrimental effect upon fatigue. In 0.75% C rail steels, 0.15 to 0.20% As was found to have no adverse effect upon strength and impact after aging for nine months. Their investigations also established that weldability of rimmed and killed low-carbon steels was not affected until arsenic exceeded 0.20% and then low-temperature embrittlement of welded joints occurred.

Toolsteels

As in the Western industrial countries, toolsteel development in the Soviet Union has been determined by the requirements of metalworking machinery. During the '30's, principal attention was paid to the high speed steel group. Until 1935 only one composition, 18-4-1, was used. From 1935 to 1940, additional steels, summarized in Table IV, were added.

Steels ЭИ116 and ЭИ172 used cheaper chromium (instead of tungsten) at the expense of red hardness. Steel ЭИ184 possessed red hardness up to 1025° F., while red hardness of 18-4-1 high speed steel held up to 1110 to 1140° F. The former steel, used until 1947, has since been replaced.

The second group contains compositions of lower tungsten content, with four carbide-forming elements. Increased vanadium content in steel ЭИ276 is detrimental to its grinding qualities, but increases its red hardness to 1110 to 1130° F., almost that of 18-4-1. Steel ЭИ290 is better for grinding but has inferior red hardness and is sensitive to decarburization.

Steel ЭИ262 of the third group has increased vanadium content to enhance its red hardness;

Table VI – Soviet Forging Die Steels

Grade	C	Mn	Si	Cr	Ni	W	V	Mo
5XHM	0.50-0.60	0.5-0.8	0.35 max.	0.5-0.8	1.4-1.8	—	—	0.15-0.30
5XHB	0.50-0.60	0.5-0.8	0.15-0.35	0.5-0.8	1.4-1.8	0.4-0.6	—	—
5XHC	0.50-0.60	0.3-0.6	0.6-0.9	1.3-1.6	0.8-1.2	—	—	—
5XHCB	0.50-0.60	0.3-0.6	0.6-0.9	1.3-1.6	0.8-1.2	0.4-0.6	—	—
5XHT*	0.50-0.60	0.5-0.8	0.35 max.	0.9-1.25	1.4-1.8	—	—	—
4X6B6C	0.35-0.45	0.4-0.6	1.2-1.4	6-7	—	6-7	0.5-0.6	—
4X3B8M	0.35-0.45	0.5-0.6	0.3-0.4	3-3.5	—	8-9	0.4-0.6	1-1.2
4X3B2M2Ф	0.35-0.45	0.5-0.6	0.3-0.4	3-3.5	—	2-2.5	1.5-2	2-2.5
4X3M6BФ	0.35-0.45	0.5-0.6	0.3-0.4	3-3.5	—	1-1.5	0.5-0.7	5.5-6

*Contains 0.08 to 0.15% Ti.

Table VII – Extrusion Die and Die-Casting Steels

	C	Mn	Si	Cr	Ni	W	V
3X2B8	0.30-0.40	0.2-0.4	0.35 max.	2.2-2.7	0.3 max.	7.5-9.0	0.2-0.5
4X8B2	0.35-0.45	0.2-0.4	0.35 max.	7-9	0.3 max.	2-3	—

Russian Steel Nomenclature

In Russian steel nomenclature, the number with which each designation starts specifies carbon content in tenths or hundredths of a percent. Following are letters of the Russian (Cyrillic) alphabet which stand for the alloying elements: X – Cr, Г – Mn, C – Si, M – Mo, Д – Cu, H – Ni, B – W, Ф – V, and T – Ti. Numbers following these letters specify alloy content in percent. Letter A at the end signifies special quality steel, and letter Л a casting composition. For example, 4X3B8M stands for steel with 0.40% C, 3% Cr, 8% W, and 1% Mo.

its cutting qualities are equal to those of 18-4-1 in machining cast iron and steels of hardness up to Brinell 220 to 250.

Since World War II

With the large postwar growth of Russian industry, a great variety of toolsteels was developed. Sixteen carbon toolsteels are now available; typical of these is Y12A. Containing 1.15 C and 0.20 Mn (with a maximum of 0.30 Si, 0.20 Cr, and 0.25 Ni), it is used for cutters, reamers, broaches, twist drills, files, coining dies, metal saws and other small tools.

Among alloy grades, 9XC (0.90 C, 0.45 Mn, 1.40 Si, 1.10 Cr, 0.3 Ni max.) and XBГ (0.95 C, 1.35 Cr, 1.40 W, 1.0 Mn, 0.10 V) are most widely known. The former is used for drills, broaches and milling cutters, while the latter is a nondeforming grade for tools with complex shapes.

High speed steels such as the standard 18-4-1 and 9-4-2 grades have been used by the Russians since the 1930's; however, development of difficult-to-cut heat resistant steels and nonferrous alloys found these old standbys wanting in tool life and ability to maintain high cutting speeds. Several new compositions, containing cobalt and higher vanadium, have been added; they are listed in Table V.

While a high-vanadium steel, such as P10Ф, is dispersion hardening and can consequently retain red hardness up to 1155 to 1165° F. with 3 to 4% increase in cutting speed, it is hard to forge and grind. In PK5, a similar improvement in cutting speeds was obtained by adding 4 to 5% Co, resulting in red hardness up to 1110° F. However, the high cost of cobalt steels limits their application.

Due to these limitations, 18-4-1 and 9-4-2 are still the standard high speed steels used in the U.S.S.R.; future efforts will be directed toward developing dispersion hardening alloys containing 15% Co and 18% W. These iron-base alloys have been hardened to Rockwell C-30 to 35 and aged at elevated temperatures to Rockwell C-66 to 67. Research will aim at decreasing their brittleness by proper alloying.

Typical Soviet die steels for hot forging are listed in Table VI. Steels 5XHC and 5XHT are used for smaller die blocks (smallest dimension up to 8 to 12 in.), while 12 to 16-in. die blocks used 5XHB and 5XHCB. For die blocks with minimum dimensions exceeding 16 in., with deep and asymmetrical die impressions, and which must withstand heavy shock and bending loads, steels 5XHCB and 5XHM are used. The last four compositions in Table VI have been developed to hot forge heat resistant alloys. These steels are currently being tried under production conditions. Table VII lists typical hot extrusion die and die-casting steels.

Other Toolsteel Developments

The Russians appear to be familiar with the latest heat treating methods for toolsteel, such as martempering, austempering, subzero treatment, and steam treatment to enhance cutting qualities and corrosion resistance. They are currently analyzing the theoretical and practical aspects of tool failures with a view to improving their mechanical properties. Opinions have also been expressed that better toolsteel quality can be achieved by improved production methods.

Vacuum Techniques Are Useful

The Russians are beginning to make considerable use of vacuum techniques. Some of the more concrete achievements in this field follow:

- Transformer steels are being vacuum melted to increase electromagnetic properties and improve plasticity so that cold rolling of higher-silicon steel is more practicable.
- Cr-Ni stainless steels are being induction melted to reduce intercrystalline corrosion. Vacuum melted steel has higher resistance to corrosion in boiling HNO_3 due to lower carbon content and absence of titanium.
- Vacuum degassing reduces watt losses of transformer steels 10 to 15%, carbon is lowered to 0.02 to 0.03% and sulphur to 0.003 to 0.005%.
- Vacuum degassing is widely used, as it is here and in Europe, to reduce flaking and increase plasticity of rotor steels.

A Prominent American

Henry Hickman Harris

Metals Engineer

For services rendered to the furtherance of Brazilian-American friendship, the Brazilian Government has awarded the medal of its National Order of the Southern Cross to Henry Hickman Harris, extraordinary, alloys-wise casting engineer, president of General Alloys Co. (Boston), major stockholder of Alloy Engineering & Casting Co. (Champaign, Ill.), and – to expand his industrial contacts to the international scene – owner of H. H. Harris Engineering Services (Boston and Santiago). Another honor of which he is justly proud is the Trinks Industrial Heating Award "for outstanding achievement in development of high-temperature furnace mechanisms and heat treat tooling".

For the U. S. Armed Services he completed a ten-year series of research and development projects. The goal was to cast steel, high-alloy and light metal into shapes with strength-weight superiority to forgings. Before this goal was achieved, many advanced processes were devised. Mechanical, hydraulic, electronic and vacuum machines and controls were designed and developed during these projects, as was a complete ceramic processing plant for the manufacture of cores and molds of highest precision. Dimensional accuracy as well as high physicals was achieved.

The subject of this biographical appreciation is the seventh generation of a colonial American family from which came able philanthropic Quaker and Methodist farmers, preachers, cattlemen, bankers, publishers, manufacturers. Having left school to train for aviation in World War I, and then being too young for active service, he became manager of the calorizing department of the Diamond Power Specialty Co. in Detroit. Sensing the need for high-temperature alloys, he attended the University of Wisconsin as a special student and crammed the fragment of the then-applicable metallurgy. He incorporated General Alloys in 1922. This he advertises as "the world's first exclusive manufacturer of heat and corrosion resistant castings".

He crossed frontiers in producing, for Ford Motor Co. of Canada, a tremendous "lead pot", 65 ft. long and 56 in. wide and about as deep, welded of alloy plate (68% Ni, 18% Cr). He cast, as a virtuosity, all necessary parts of a clock that kept good time at 2000° F. (exhibited at the Metal Show in Philadelphia in 1928). Another unsurpassed achievement is the 10-ton, 18 by 20-ft. stainless plaque on the facade of the Associated Press Building in New York.

For his fun, "Harry", as he is known to countless acquaintances in the metals industry, engineered his own aerial camera, snapped photos of his customers' plants and homes as he soloed low and slowly over them; tricked up an amphibious military DUKW into a traveling hostel and sales office and once navigated it the 25 miles across Nantucket Sound through a storm. A member of the Sons of the American Revolution, a founder member of the American Legion, and a sentimental patriot, he vigorously supported the campaign to rebuild the frigate Constitution ("Old Ironsides"), receiving a longboat anchor and a piece of the rudder chain from the old ship, which he personally welded into andirons for the huge fireplace of his Champaign study. Above the mantelpiece (an oak stanchion from the Constitution's gunwale) is a portrait of his father, Benjamin Franklin Harris III, idealistic Illinois banker who founded the U.S. county farm-agent movement, whom Harry Harris reveres even more than he does his sturdy great grandfather, Benjamin Franklin Harris I, Illinois cattleman who drove his stock the thousand miles to Philadelphia and Baltimore markets.

Each Christmas he retreats from all business affairs and gives parties with presents and goodies to the children of the Boston and Champaign personnel, mails 10,000 mementoes to his friends around the world, and evaluates himself. "I see friendships that are ripening, that have stood the test of years. Have I kept faith with those who trusted, or am I in arrears? . . . In this life I have acquired a few ideals and loyalties, and I dislike having them desecrated . . . I am humble as I contemplate how little has been accomplished and how much remains to be done; but, believe me, my zest for the quest of knowledge has but sharpened with the years."

Myron Weiss

Metals for the Future . . .

The Rare Earths

*By R. B. HOWES**

Ion-exchange separation, developed during World War II, helped these little-known metals to achieve individuality. With purer metals and oxides available, these metals are now being used as scavengers for steel melts, sources for X-rays and getters for vacuum pumps. In the future, their unique nuclear properties will probably make them valuable as structural materials in reactors. (A-general; EG-g, 17-57)

ONE QUARTER of all the metallic elements are in the group known as the "rare earths" or lanthanons. Occupying positions 58 through 71 in the periodic table (though including No. 39, yttrium), these metallurgical latecomers are not earths, chemically speaking, nor are they rare, geologically speaking.

Their early history is one of accidental discovery. At first, confusion due to the limited chemical techniques for separation and purification led to inaccurate classification. It was not until 1920 that the rare earths were accurately cataloged, but reduction and purification of the metals was so costly that most investigators never saw or handled them except in impure combinations such as "misch metal". The breakthrough in separation techniques took place during World War II at the Institute for Atomic Research, Ames, Iowa. Under the direction of Dr. Frank Spedding, ion-exchange techniques were developed; these achieved purities of individual oxides running as high as 99.99%. With costs less than one-fiftieth of previous methods, bulk quantities of the entire group of rare earths become available at lower prices and higher purities.

In general, fruitful research on rare earth oxides sparked an interest in the individual rare earth metals themselves. Displacement reactions using such materials as aluminum, barium, calcium, sodium, potassium and magnesium have been the most successful for production of high-purity metals.

*President, St. Eloi Corp., Cincinnati, Ohio.

Presently, rare earth fluorides are displaced with magnesium or calcium in a proper flux. In theory, pure oxide is converted to fluoride of equivalent purity, and the fluoride is heated with calcium under vacuum. This is meant to yield an ingot with calcium fluoride floating on top. Practically, many difficulties arose in the reduction process. Impurities increased with each step since most molten rare earth metals are so active that they dissolve crucible walls, and even under vacuum, the metals absorb gases. Production and storage of metals required inert atmospheres. Eventually, by using tantalum crucibles for the melt, specially engineered furnaces, and extreme care in each step of the process, high-purity metals in reasonable quantities were produced. (Samarium, europium and ytterbium cannot normally be prepared by displacement with non-rare earth metals, but require previously prepared rare earth metals for reductants.)

All the rare earth metals are available commercially. Although prices are still high, production is increasing. This promises to bring prices down.

Properties Are Variable

Although the rare earths are shown as occupying positions 58 through 71 in the periodic table, in practice they include No. 57 (lanthanum) and No. 39 (yttrium). There are but 15 elements to work with; No. 61 (promethium) is available only through nuclear fission or fusion processes – it is, itself, unstable. The rare earths resist

ordinary chemical procedures since they all have a valance of three. However, they exhibit striking differences in their chemical behavior and are definitely not unreactive. The predominant valence is +3, although cerium exhibits a +4 valence as do praseodymium and terbium, while samarium, europium and ytterbium can exhibit a +2 state.

As mentioned above, yttrium, although technically not a rare earth, is chemically similar and occurs naturally with the rare earths in most ores. Producers offer yttrium, since it automatically becomes one of the products of any rare earth separation.

A glance at the oxidation potential in the Data Sheet, p. 112-B, reveals that oxidation potentials of the rare earths are higher than calcium and lower than sodium. They therefore are good reducing agents. Ingots have a silvery luster when initially cooled, but a few tarnish rapidly when exposed to moist air at room temperature. Hardnesses vary from Vickers 35 to 70 in proportion to their boiling points. Hardness is increased by small amounts of oxygen – a common impurity – but most other contaminants also affect hardness strongly one way or the other. Densities vary from below that of iron to just above it.

A property which excites a great deal of interest is the wide variability in transparency to thermal neutrons exhibited by the group. This ranges from a low of 1.27 thermal barns for yttrium to 46,000 thermal barns for gadolinium. Obviously, they can be useful as structural and shielding materials for nuclear power reactors and other devices employing atomic fission. Gadolinium is magnetic, and neodymium, cerium and dysprosium exhibit weak ferromagnetism at low temperatures. The lattice constants and ionic radii show that these metals should, in theory, fit into the lattice structures of copper, aluminum, iron and some other metals to form new alloys. Scrutiny of the Data Sheet (p. 112-B) will suggest many uses of the rare earth metals in alloy systems and miscellaneous applications.

Metallography – Techniques to Use

Preparation of the individual rare earth metals for accurate and reproducible metallography is a time-consuming and tedious process at best. One of the easier metals to prepare is yttrium; being fairly stable it can be easily cut and mounted for metallographic examination. However, the rare earth metals run the gamut in rapid oxidation. The most unstable is europium which, when taken directly from a distilling chamber, will spontaneously revert to an intense yellow compound and then to a typical oxide. Primary conversion is very rapid and is normally accompanied by much sound and fury. In the early days it was most disconcerting to have a beautifully prepared distillate suddenly erupt in one's face for no visible reason. Handling techniques now include careful transportation under protective atmospheres or in vacuum. In preparing a sample of europium, only the most dedicated worker can ever hope for success since, in addition to its inherent pyrophoricity, the material is very soft and extremely difficult to polish without producing scratches.

Samarium, neodymium, cerium and lanthanum present somewhat similar problems for metallography except that processing is easier. In general, dysprosium, holmium, erbium, terbium and yttrium may be polished with pure water if only a somewhat superficial examination is desired. All rare earth metals may be polished with either kerosene, methyl alcohol, ethyl alcohol or other nonreactive organic solvents. The less reactive metals can be lubricated with mineral oil when sawed.

Careful research has indicated that *any* technique can result in misleading interpretations. This is due primarily to the technique, and not to the actual properties of the system under study. Somewhat impure samples of metals do not require the more careful approach since certain impurities stabilize these metals from a metallographic standpoint. But, as higher purities are approached, metallography requires careful attention; unfortunately, no hard and fast rules can be laid down.

Lubricant for Polishing

The best lubricant found for grinding and polishing the entire series has been high-purity methyl alcohol. Ordinary wet belt grinding followed by low-speed coarse grinding and finishing with high-speed 600 paper is usually satisfactory. Final polishing should be done on a good grade canvas duck; the sample is finished with silk and the best grade alumina available. The more reactive metals must be kept wet at all times so that atmospheric etching does not take place.

Metallographic examination may require, for the more reactive metals, a small well or cup containing water-free oil which is situated directly over the specimen. Acid and halide etches are used. For general purpose work, a simple nital

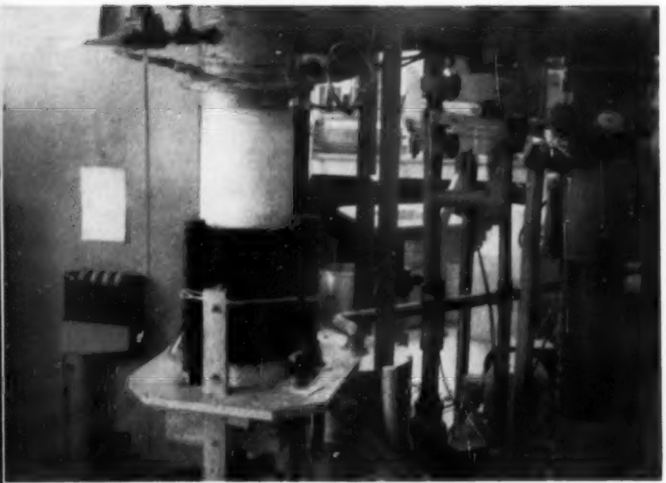

Fig. 1 — Quartz Induction Furnace and Vacuum Pumping System for Reduction of Rare Earth Metals. Five of these are being used at this time

etch is satisfactory. In combination with HF, nital will bring out satisfactory grain structures and reveal grain boundaries on a well-polished specimen.

Inclusions in most specimens are best revealed with bromate etches containing either carbonates or glycerine to modify attack. In the more reactive samples, air etching will exhibit interesting surface effects. Plastic deformation in the pure metals is so pronounced that a thoroughly undisturbed surface is difficult to produce. However, most of the disturbed surface (of more reactive metals) can be removed by electrolytic etching in glycerine to which a trace of water has been added.

The principal contaminants are oxyfluorides and fluorides (dark to black inclusions), oxides or suboxides (pale yellow to gray inclusions), and metallic phases which normally arise from vessels used for reduction and casting. Calcium-rich areas which may serve as focuses for attack are easily seen with nearly any etching technique. Grain-boundary precipitation is pronounced with several common crucible metals, such as tantalum, titanium, zirconium and molybdenum.

Electrochemical Properties

Since the rare earth metals are markedly electropositive, chemical attack by other anions or gases would be expected to proceed at a fairly high rate. This is true except where they can be passivated. This is possible with several rare earth metals; specimens of these will stand for long times without surface deterioration.

Polarized light is helpful in determining grain boundaries and grain structure, but its more important use is in the identification of inclusions. Extremely pure metals (those prepared by repeated vacuum distillations) show wholly different responses to metallographic techniques. Indeed it is possible to discriminate among specimens on a rough basis as to their intrinsic purity because of these responses.

Protection From Corrosion

Though rare earths are used commercially as additives to various ferrous and nonferrous melts, little has been done with structural applications. Their high activity (which has made them useful as scavengers in metals) has deterred direct application. Most previous work is suspect because large quantities of impurities were probably present. Economics has played a strong role, but with expansion of the industry very substantial price decreases should follow.

Protection of metals in the group with conventional electroplates is now being studied and shows promise. Nickel and copper plating, followed with chromium, is usually possible with suitable preparative techniques. Direct electroless nickel plating is feasible especially with the less reactive metals. Cladding with more expensive metals (such as gold and silver) is not required. Since most of the rare earth metals are reasonably volatile at high temperature in vacuum, they may be readily deposited on to appropriate substrates. Coatings of protective metals may be deposited to provide protection.

Metal Deposition

A nonaqueous bath has been developed for plating gadolinium onto copper in films up to 0.1 mil thick. (Samarium and europium show similar properties.) These baths can be made and replenished from salts of the rare earths; this eliminates use of the more expensive metallic form. Analogous to plating solutions are the rare earth metal resinates. These are compounds containing the elements bound in an organic complex; they permit application to a porous or a semiporous surface. The resinate is sprayed or brushed on, and the piece is fired in an atmosphere which removes the organic carriers and leaves an oxide film. A metal film may be deposited under appropriate conditions.

Applications for Rare Earths

Nucleonics is the field in which rare earths are bright with promise. Yttrium, for example, is nearly as light as aluminum but is structurally more similar to titanium. This, combined with its low neutron cross-section area, makes it potentially valuable as a structural material for

Fig. 2 – Tantalum Crucibles (Used and New, Respectively) for Reducing Rare Earth Metals. The ingot on the left is gadolinium, the other is terbium

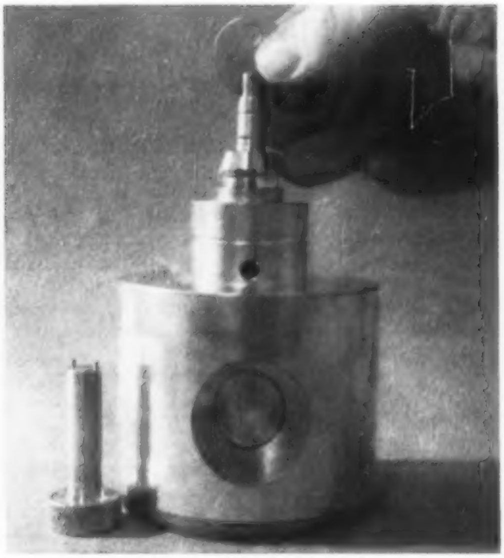

Fig. 3 – Thulium X-Ray Generator. Powered by irradiated thulium buttons, this generator is made of free-machining brass. Three safety locks help reduce radiation to about 0.05 milliroentgen at the surface

atomic power reactors. Gadolinium and europium can be used as thin, lightweight nuclear shielding for aircraft and in protective clothing where insulation from thermal neutrons is required. In fact, nuclear bombardment transmutes europium to gadolinium; this multiplies its absorption factor by almost ten. Samarium, much more common (and therefore cheaper), is being considered for a shielding material where weight is less critical. Their high cross section makes these rare earths valuable as constituents of efficient control rods for atomic reactors. General Motors is looking at a radioisotope of samarium (Sm^{153}) as a source of X-rays for metallurgical control of castings. (Thulium has been tried as an X-ray source for underwater inspection of piling.)

Another unique use is the detection of low-level neutron radiation on a quantitative basis. Dysprosium can be rolled into thin foils, the neutron cross sections of which are accurately known. If neutrons are allowed to interact with these foils, radiation activities of known duration are induced. These can be read directly as amount of original radiation, or the count may be translated with suitable conversion tables. The foils are small and portable.

Electronics offers a promising field for rare earth applications, particularly gadolinium which is ferromagnetic, and may be useful for creating new magnetic alloys. Combination of the oxide with other oxides to form magnetic ceramics (known also as iron garnets) has passed the experimental stage. Yttrium, samarium, hol-

Potential Uses for Rare Earth Metals

1. Optical glass with high refraction index.
2. Portable "X-ray" camera powered by irradiated thulium.
3. Structural and shielding materials for nuclear reactors.
4. Radiation counters.
5. Magnetic ceramics and magnetic alloys.
6. High-temperature batteries.
7. Scavengers for molten metals.
8. Strengthening agent for metals and alloys.
9. Aid for producing high vacuums.
10. Ceramics with better heat radiation and electronic properties.
11. Semiconductor and rectifier alloys.
12. Efficient thermo-electric power sources.
13. Stabilized heating elements.
14. Transducers for measuring high pressures.
15. New rocket fuels.

Cover Shows Rare Earth Refining Furnace

The spectacular picture on the cover illustrates a rare earth refining furnace in action. Heated by an induction coil which surrounds the evacuated glass chamber, the fluorides are reduced. Metal flows into a suitable crucible (Fig. 2) which is also within the double-walled chamber. A coolant is circulated between the walls and through the supporting electrodes.

When operation begins, a high-frequency induction field is generated, and skin melting occurs. Various impurities are freed – they migrate to the retaining walls, or volatilize into a trap – as metal collects in the crucible. The fiery display erupting from the top is due to gases released by the molten metal. Since they are in a high vacuum and under a high electrical potential, they emit a characteristic glow in the same manner as a neon lamp. The hot electrode also glows, and a cathode discharge occurs around the crucible. All of these lighting effects combine to form Fourth-of-July pyrotechnics which would not be out of place in a science-fiction movie.

mium and erbium have also been combined with other oxides to create nonconducting magnetic substances with low hystereses. These materials can be tailored to fit both the electrical and structural requirements of any device.

Currently, much research is going into the development of devices which produce power through thermo-electric effects. In trials for high-temperature batteries, praseodymium, cerium and lanthanum oxides have been successfully tested in crude cells which yield as much as 1.4 v. at 950 to 1400° F. At these temperatures such devices produce a voltage with no temperature differential across the junction as in an ordinary thermocouple. Work has also been done on room-temperature batteries employing rare earth salts. The experimental models were rechargeable using an ion exchange resin as a confining matrix.

Metallurgy Holds Much Promise

In this field, much research effort has been expended. Misch metal mixtures have proved helpful in steel production. For instance, stainless steels are easier to roll and have better corrosion resistance when misch metal is added to the melt. Some rare earths improve impact resistance of armor plate. Trace quantities of pure rare earths added to alloys have been found to increase high-temperature strength. Changes in the strength and high-temperature characteristics of stainless steel, nickel, cobalt-nickel, nickel-chromium, chromium, chromium-iron, aluminum, magnesium, titanium and copper have been observed.

Yttrium is already considered on the way to becoming the newest "wonder metal" in the aviation industry. A little more than halfway between iron and aluminum in density, it has been combined with an aluminum alloy experimentally to yield an alloy with hardness equal to that of steel (bright-phase hardness of Rockwell C-65). There is still much to be learned of the metallurgy of rare earth metals since pure samples have not been available for research and testing until recently.

In high-vacuum work, yttrium has good gettering qualities. Diffused on the inner wall of a high-vacuum chamber, an yttrium film will help to pump down and hold a vacuum of less than 0.01 micron. This can be done with equipment that could not otherwise be pumped below 0.02 to 0.03 micron, and would rapidly leak up to 1.0 micron as soon as the pumping machinery was turned off.

Future Is Bright

As with other unfamiliar materials, future uses of the rare earths are limited only by the imagination and the amount of work spent in investigating their properties. Some applications that seem reasonable are: ceramics with enhanced heat radiation and electronic characteristics; magnetic alloys and ceramics possessing very high field strengths; new semiconductor and rectifier alloys; high-efficiency thermo-electric power sources; stabilized heating elements with tenfold increase in lifetime; transducers for pressure measurements up to 50,000 atmospheres; alloys of light weight with better high-temperature strength; new rocket fuels; portable neutron detectors; commercial plating solutions of rare earth metals; alloys possessing new inertial characteristics through response to electromagnetic fields.

Ten years from now, it will be interesting to look back and observe how the rare earth metals have been exploited by industry.

Some Properties of the Rare Earth Elements

These data were compiled by St. Eloi Corp. from numerous sources, but special reference should be made to WADC Technical Report 57-666.

PROPERTY	Y	La	Ce	Pr	Nd	Sm	Eu
Atomic number	39	57	58	59	60	62	63
Atomic weight	88.92	138.92	140.13	140.92	144.27	150.35	152.0
Density, g/cc. (density by X-ray in parentheses)	4.472	(6.162) 6.19	(6.768) 6.73	(6.769) 6.78	7.007	(7.54) 7.49	5.245
Melting point, ° C.	1552	920 ± 5	804 ± 5	935 ± 5	1024 ± 5	1052 ± 5	826 ± 10
Boiling Point, ° C. (estimated)	3030	4230	2930	3020	3180	1630	1490
Crystal habit	hcp.	hcp. / fcc.	hcp. / fcc.	hcp. / fcc.	hcp.	rhom.	bcc.
Lattice constant, Angstrom units	a = 3.64, c = 5.73	a = 3.76, c = 12.15 / a = 5.30	a = 3.65, c = 5.96 / a = 5.16	a = 3.61, c = 11.83 / a = 5.15	a = 3.65, c = 11.79	α = 23°13′	4.59
Specific heat at 0° C., cal./mole/° C.	6.01	6.65	6.89	6.45	7.20	6.49	6.00
Δ H fusion, kg-cal./mole	4.1	2.4	2.2	2.4	2.6	2.6	2.3
Δ H vaporization, kg-cal./mole	94	93	92	79	69	46	40
Atomic radius, Angstrom units	1.80	1.870 / 1.872	1.81 / 1.817	1.824 / 1.821	1.818	1.804	2.042
Atomic volume, cc.	19.7	22.43 / 22.48	20.7 / 20.58	20.79 / 20.71	20.60	20.0	29.00
Thermal conductivity, cal./sq.cm./cm./sec./° C.	0.035	0.033	0.026	0.028	0.031	—	—
Specific resistivity at 0° C., ohm-cm. × 10^{6}	80	62.4	76.7	73.7	71.8	88.0	81.3
Temperature coefficient of resistivity, ° C. per ° C. (R.T.)	0.00271	0.00218	0.00087	0.00171	0.00164	0.00148	0.00480
Atomic susceptibility, cgs. (room temperature)	Low +	115 × 10^{-6}	~700 × 10^{-6}	5470 × 10^{-6}	3460 × 10^{-6}	1320 × 10^{-6}	224 × 10^{-6}
Young's modulus, dynes/sq.cm. × 10^{-11} (calculated)	6.63	3.84	3.00	3.52	3.79	3.41	—
Shear modulus, dynes/sq.cm. × 10^{-11}	2.62	1.49	1.20	1.35	1.45	1.26	—
Poisson's ratio	0.265	0.288	0.248	0.305	0.306	0.352	—
Compressibility, sq.cm./kg. × 10^{6} (room temperature)	2.96	4.06	3.87	3.67	3.19	3.71	6.99
Ionic radius, Angstrom units	1.06	1.22	1.18	1.16	1.15	1.13	1.13
Oxidation states	III	III	III, (IV)	III, (IV)	III	(II), III	(II), III
Oxidation potential, volts	2.37	2.52	2.48	2.47	2.44	2.41	2.41
Neutron absorption cross section of oxide, thermal barns	1.38 ± 0.14	8.9 ± 0.3	0.70 ± 0.08	11.2 ± 0.6	46 ± 2	5500 ± 200	4600 ± 400
Abundance in earth's crust, % × 10^{-5}	105	35	155	25	90	35	1
Coefficient of expansion, 400° C. × 10^{6}	—	8	7	6	8	—	26

PROPERTY	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Atomic number	64	65	66	67	68	69	70	71
Atomic weight	157.26	158.93	162.51	164.94	167.27	168.94	173.04	174.99
Density, g./cc. (density by X-ray in parentheses)	7.868	8.253	(8.565) 8.556	8.799	(9.058) 9.15	9.318	6.959	9.849
Melting point, ° C.	1350 ± 20	1360	1485 ± 20	~1490	1500 – 1550	1550 – 1600	824 ± 5	1650 – 1750
Boiling Point, ° C. (estimated)	2730	2530	2330	2330	2630	2130	1530	1930
Crystal habit	hcp.	hcp.	hcp.	hcp.	hcp.	hcp.	fcc.	hcp.
Lattice constant, Angstrom units	a = 3.64, c = 5.78	a = 3.59, c = 5.66	a = 3.59, c = 5.66	a = 3.56, c = 5.62	a = 3.56, c = 5.60	a = 3.52, c = 5.56	5.47	a = 3.51, c = 5.56
Specific heat at 0° C., cal./mole/° C.	11.20	6.54	6.72	6.45	6.60	6.45	6.00	6.45
Δ H fusion, kg-cal./mole	3.7	3.9	4.1	4.1	4.1	4.4	2.2	4.6
Δ H vaporization, kg-cal./mole	72	70	67	68	67	51	32	75
Atomic radius, Angstrom units	1.794	1.773	1.769	1.759	1.748	1.742	1.933	1.737
Atomic volume, cc.	19.79	19.11	18.97	18.65	18.29	18.12	24.75	17.96
Thermal conductivity, cal./sq.cm./cm./sec./° C.	0.021	—	0.024	—	0.023	—	—	—
Specific resistivity at 0° C., ohm-cm. × 10^{6}	140.5	—	56	87.0	107.0	79.0	27.0	79.0
Temperature coefficient of resistivity, ° C. per ° C. (R.T.)	0.00176	—	0.00119	0.00171	0.00201	0.00195	0.00130	0.00240
Atomic susceptibility, cgs. (room temperature)	Ferromag.	172 × 10^{-3}	590 × 10^{-6}	437 × 10^{-6}	300 × 10^{6}	158 × 10^{-6}	81 × 10^{-6}	179 × 10^{-6}
Young's modulus, dynes/sq.cm. × 10^{-11} (calculated)	5.62	5.75	6.31	6.71	7.33	—	1.78	—
Shear modulus, dynes/sq.cm. × 10^{-11}	2.23	2.28	2.54	2.67	2.96	—	0.70	—
Poisson's ratio	0.259	0.261	0.243	0.255	0.238	—	0.284	—
Compressibility, sq.cm./kg. × 10^{6} (room temperature)	2.58	2.45	2.74	2.66	2.63	2.72	8.00	2.32
Ionic radius, Angstrom units	1.11	1.09	1.07	1.05	1.04	1.04	1.00	0.99
Oxidation states	III	III, (IV)	III	III	III	III	(II), III	III
Oxidation potential, volts	2.40	2.39	2.35	2.32	2.30	2.28	2.27	2.25
Neutron absorption cross section of oxide, thermal barns	46000 ± 2000	44 ± 4	1100 ± 150	64 ± 3	166 ± 16	118 ± 6	36 ± 4	108 ± 5
Abundance in earth's crust, % × 10^{-5}	35	5	35	5	30	5	35	5
Coefficient of expansion, 400° C. × 10^{6}	8	10	12	—	11	—	31	—

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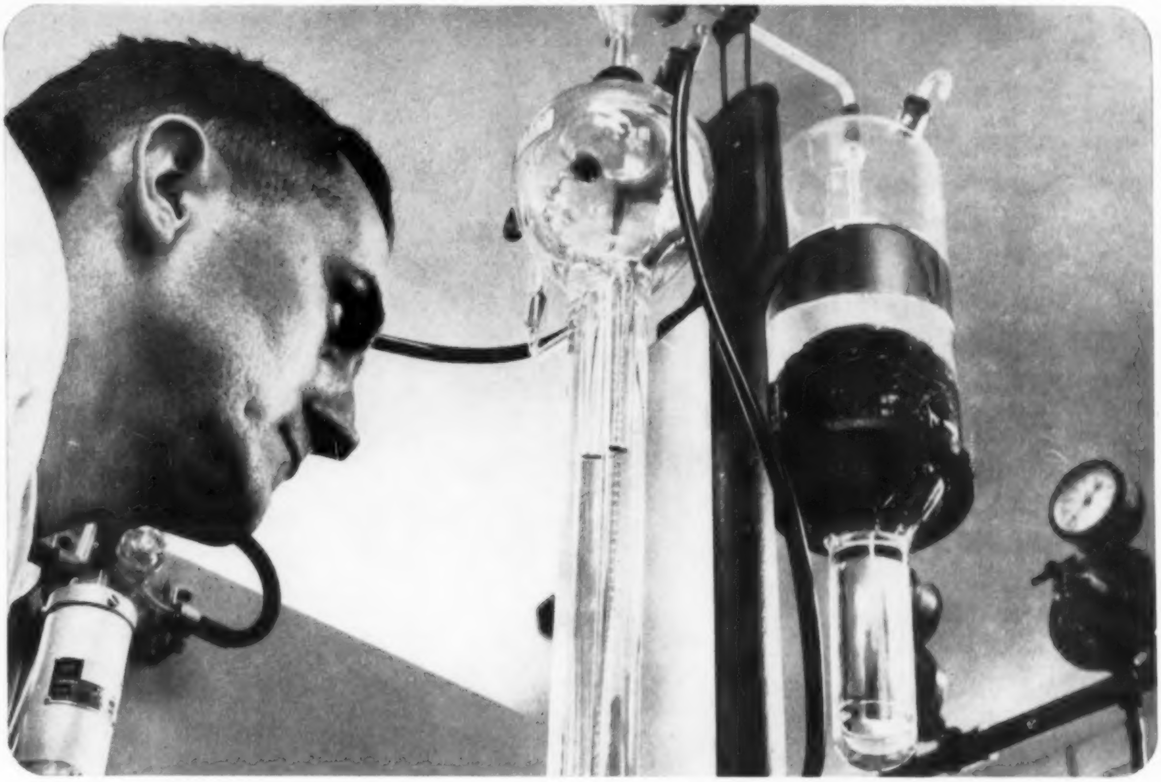

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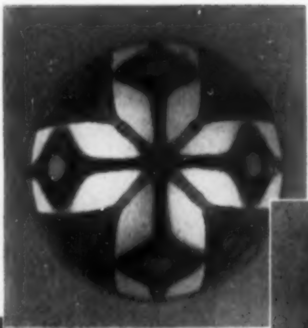

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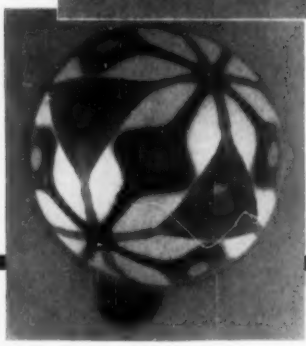

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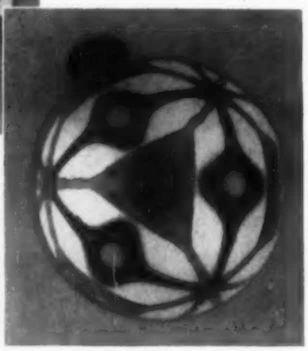

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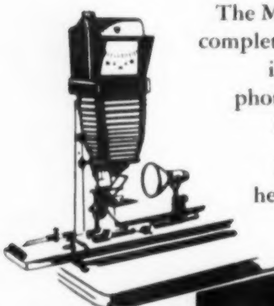

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SINCE 1853

Staff Report

Engineers Discuss Space Flight

Problems of space travel concerned the speakers at a recent meeting of the American Society of Mechanical Engineers. Ranging from the economics of booster recovery to Earth-to-Mars flights, these discussions covered practically every phase of rocket research today. (T24e, T24f)

Shades of Jules Verne! Though nominally an Aviation Conference, 64 of the 77 papers presented at the meeting of the American Society of Mechanical Engineers at Los Angeles concerned Man's coming entry into space. That a recognized technical society should devote so much time to serious discussion of space travel and its problems is significant of the changes in the last 20 years. In 1939, engineers talked of designs and materials for automobiles and airplanes; interplanetary trips were relegated to the science fiction magazines. However, the intervening years have brought such a rush of scientific progress that few eyebrows were raised at the preponderance of space technology.

The men gathered for the A.S.M.E. meeting were interested in several areas of space flight. One main topic was economy. Readers of the daily papers are aware that satellites, both Russian and American, are zooming around the world several times a day. They are also aware that these small items are rather expensive – payloads run about $1,000,000 per lb., at present. Though our rocket pioneers operate on government funds, they admit that these costs are much too high to permit large-scale development, and are making every effort to lower them. One method for cutting costs lies in the recovery of the first booster – the largest, most complicated, and most expensive stage of any rocket. As discussed by H. H. Koelle of the Redstone Arsenal, several recovery schemes (employing

parachutes, wings, turbojet-assisted rocket boosters, and pure rocket boosters) have been proposed. Though much depends upon the number of times the booster is expected to be used (if it is used often, the recovery system can be more elaborate), the best method appears to be a parachute-rocket combination. In this, rockets are fired to slow the booster's dive to destruction and the parachute opens. After it has settled, it can be picked up and reused. Savings of 15% or more are expected.

Jet Versus Nuclear Power Plants

Another scheme for booster recovery was discussed by P. G. Kappus, General Electric Co., who believes that an air-breathing power plant could be the answer. Essentially, this is a jet plane with the nose fitted to hold the rocket. Designed to reach a maximum 4000 ft. per sec. at 100,000 ft., the booster would release the rocket and glide back to the base. It could be piloted or guided by automatic controls. One attractive feature of this plan is the potential reliability; air-breathing jet engines have proven themselves during their years of use.

This is, unfortunately, not true of nuclear propulsion which, however, offers promise for the future. According to W. A. Moser, Rocketdyne, better performance can be expected though nuclear engines are heavier. Lighter propellants can be used, thus allowing for longer thrust time. For equivalent rockets, a 900-sec. thrust is estimated as opposed to a 400-sec. thrust for a typical chemical rocket. Radiation from the engine is a problem if the rockets are manned, but so is radiation from outer space. Protection from both is expected to offer little more trouble than protection from either.

Many people feel that the next step in the conquest of space is to place a man in orbit. However, as Martin Goldsmith, Rand Corp., pointed out, there is much disagreement as to how this is to be done. Liquid and solid fuels both have their proponents. The former appear to have the edge since they allow a few seconds for escape if accidental burn-out should occur, and the acceleration problems are not as great. With present ICBM hardware, a 2200-lb. manned capsule could be put into a 120-mile orbit. Highest acceleration, which occurs at burn-out, is estimated to be about 6½ g. This is unpleasant but endurable with proper protection.

Man, being a fragile though adaptable animal, needs more than protection from gravity, however. Air, food, livable temperatures, and protection from radiation are only a few of the other essentials in space travel, according to A. J. Cacioppo, Goodyear Aircraft Corp. Waste materials would require some means of immediate disposal, and in long trips would even have to be reprocessed. Space travelers will need strong stomachs. In his talk on environmental systems, R. A. Nau of Convair discussed some of the conditions needed in a manned space vehicle. The environmental requirements for one man are summed up in Table I. He added that a cabin with self-sealing provisions, much like a tubeless tire, would be highly desirable. With facilities to control carbon dioxide, humidity, odor, and to store the required supplies, it all adds up to an elaborate system. A lot of work will have to be done just to keep our first spaceman alive; at present, his comfort is a secondary matter.

However, psychological factors cannot be overlooked. Over a long period, both confine-

Table I – Environmental Requirements for Man

Item	Requirement
Oxygen	Partial pressure between 2.8 and 5.6 psi.
Carbon dioxide	Partial pressure less than 0.1 psi.
Humidity	Water vapor pressure, 0.015 to 0.30 psi.
Temperature	70 to 80° F.
Inert gas (nitrogen, helium)	Partial pressure between 0 and 10.0 psi.
Toxic and noxious odors	Minimum
Total heat removal	12,000 Btu. per day
Water vapor removal	1.9 lb. per day
Liquid waste removal, reclamation, or storage	
Urine	3.3 lb. per day
Fecal water	0.3 lb. per day
Solid waste removal, reclamation, or storage	0.2 lb. per day

ment and weightlessness could cause anyone's morale to collapse. Confinement, in itself, is a minor problem as A. E. Hickey, Jr., of Electric Boat brought out in his talk concerning the nuclear submarine as a manned satellite laboratory. In a sense, submarines and satellites are similar; they must both operate in strange environments. In the sub, men proved capable of efficient work for long periods in foul-smelling regenerated air. However, they didn't like it much, as the following quoted interview with a returning sailor shows:

"Were there any fights during the trip?"

"No."

"Did anyone go off his rocker?"

"No."

"Well, didn't you get sick of the routine?"

"Oh, it wasn't so bad."

"Then you're ready to sign on for another two months' cruise?"

"No."

This interview leads to speculation as to whether space travel will be very popular after the first thrill has faded away.

"Free Fall" a Problem

Weightlessness is another matter, since there is no good way to reproduce this phenomenon experimentally. As the situation stands today, no one can be sure of a person's reaction to a state of constant "free fall". For short times there appears to be little trouble, E. L. Brown, Wright Air Development Center, reported. As director of zero gravity research for the Air Force, he has supervised experiments carried out in a Convair C-131 B transport. When this plane is flown in the trajectory shown in Fig. 1, weightlessness is produced for 12 to 15 sec. Personnel tested under these conditions could maneuver and manipulate switches with ease after some practice, but some suffered extreme disorientation. Though these short times are of some help in assessing individual performance, no one can predict the effect of long periods of zero gravity. The real test will come with the first actual space flight.

Sky-High Watchtower

The first job of our future spacemen is expected to be the assembly of a space station. This has its problems, as the paper by W. H. Clohessy and R. S. Wilshire, both of the Martin Co., pointed out. Positioning of the first subassembly, which will contain the power supply and radar tracking equipment, is merely a matter of locating it in the required orbit. The hard part comes in trying to spot the subsequent subassemblies in the vicinity of the first one. Considering the sizes, speeds and distances involved, this is something like shooting a flying pheasant from a moving train 10 miles away. With present equipment, the authors think that the subassemblies can be spotted within 100 miles of each other *providing* the actual launch time is within 10 sec. of the preselected launch time. Obviously, precise orbit calculations and rocket fuel charges are essential.

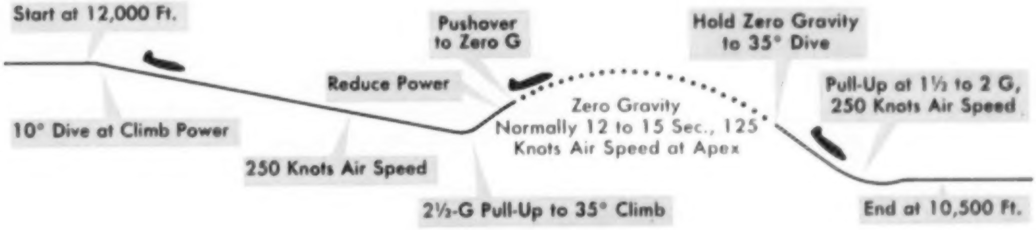


Fig. 1 — Trajectory Flown by C-131 B Transport to Produce Zero Gravity. Under weightlessness, subjects could maneuver and operate switches, but some reported extreme disorientation

One of the requirements in space station erection is auxiliary rocket power for personnel and supplies; this was discussed by J. A. Bottorff and H. B. Ellis, Aerojet-General Corp. They suggest an engine, similar to that used by Buck Rogers in the comics, which would use fuels that ignite on contact and operate at low pressures. These requirements would insure, they feel, maximum safety, reliability, versatility and performance.

Providing auxiliary power for the satellite itself is another problem. While the solar batteries used in the Vanguard have proven dependable for months, the wattage supplied is much too small to answer the needs of a large manned satellite. However, solar-energy converters could

be uprated to supply a few kilowatts according to J. H. Huth, Rand Corp. For larger amounts, nuclear reactors are expected to provide the answer.

Several secondary power schemes were compared by A. P. Kelley, AiResearch Mfg. Co. He favored a heat engine in a closed system operating on a Rankine cycle for large wattages, but conceded that it needed much development work.

It is easy to see that putting a man in space is not a simple matter. A tremendous amount of development work will be needed to provide him with the merest essentials for living. Adding power supplies and a way to return him safely – both are mandatory – makes an incredibly complicated package which is far beyond our capabilities at present.

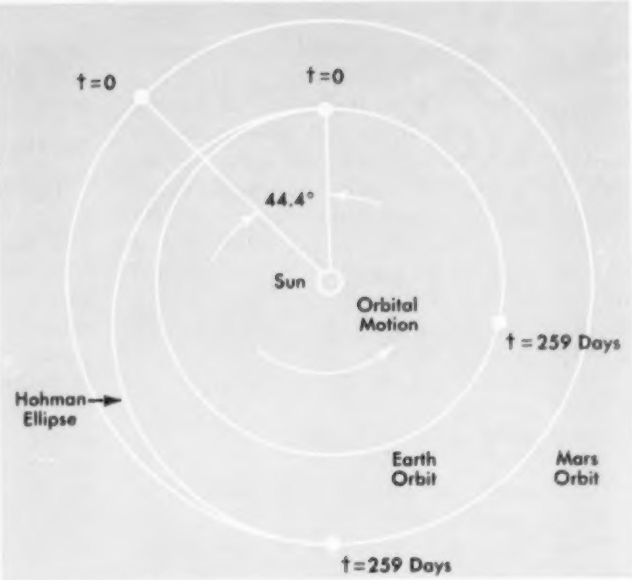


Fig. 2 – Hohman Transfer Ellipse for Earth-to-Mars Flight. This route takes time, but uses less energy than any other method

However, optimism is so prevalent that time estimates for this achievement rarely go beyond 10 years.

From Space Stations Onward

After the space station is manned and fully functional, its crew will probably set to work on ships intended to investigate Mars and Venus. Mars is expected to be the first target of an unmanned but highly instrumented vehicle, according to R. S. Kraemer and V. R. Larson of Rocketdyne. In their comparison of several propulsion systems for the Mars mission, they concluded that a liquid system of fluorine and hydrogen would offer the best payload capability in the near future. The Hohman orbit, pictured in Fig. 2, requires the least power; consequently, their calculations were based on its use. Ion and nuclear propulsion systems – both can handle greater payloads – will probably be available about 1970.

The power needed to transmit information during a Mars mission runs into hundreds of kilowatts, according to J. H. Fisher and W. R. Menetry, Electro-Optical Systems. At present, solar and nuclear energy sources appear the most feasible, but both require much improvement. Adding to the weight of any system will be the armor needed to protect equipment from flying meteorites. Obviously, impact from such items would spoil the efficiency of any solar radiation collector, but without data it is almost impossible to estimate any of the actual effects.

Another problem is the penetration of planetary atmospheres; this subject was covered by C. Gazley, Jr., Rand Corp. As far as space travel is concerned, atmospheres have both advantages and disadvantages. While they act as a "cushion" to slow down re-entry, friction can generate enough heat to melt the skin if the approach is too rapid. One suggested entry method is a glide approach. The rocket enters the atmosphere at a shallow angle, and slows gradually to avoid overheating. Alternately, the vehicle might enter directly and decelerate rapidly while depending on absorption of the heat by the body surface. The first scheme would probably be used by manned vessels, but the second, which is potentially more dangerous to human life, would be more applicable to unmanned ships.

This and many other difficulties remain to be solved by engineers before space travel is a reality. Already, the vast amount of money soaked up by research is causing complaints in some quarters. In answering them, one might consider old Ben Franklin. When attending one of the Montgolfier's balloon ascents, he was asked, "Of what use can this possibly be?" Franklin's answer: "Of what use is a newborn baby?"

*Tests of Nuclear Weapons**

As a preliminary to any agreement to ban the further testing of nuclear weapons, an international group of scientists met at Geneva last summer to consider the problems involved in policing such a ban – that is to say of determining the location, size and time of any unannounced or attempted nuclear test. Presumably they considered explosions of 5000 tons TNT equivalent or greater. From their deliberations came the finding that a test ban could be policed by a network of 160 to 170 land stations and 10 sea stations, equipped to record continuously any earth tremors, radioactivity, sudden variations in air pressure, and the like.

Later in the fall a Conference on the Discontinuance of Nuclear Weapons Tests, consisting of representatives from United States, Great Britain and Russia, met in Geneva to work out the details of a mutually acceptable treaty. At the outset the Soviets insisted that a *permanent* ban on tests be adopted before any other issue was discussed and in mid-January the United States dropped its insistance that any agreement for suspension be renewed (or revised) annually.

Toward the end of that month, the Western plan of staffing the inspection posts was offered—namely half the technical positions, including the superintendent, in control posts located in British and American territory would be Russian citizens (and vice versa) with the remainder filled by international civil servants. The Russians insisted that the entire staffs be citizens of the country in which the post is located, with up to five foreign members as observers or "controllers". This question was referred to a subcommittee for study.

A seven-member commission is to have primary responsibility for running the entire detection system. The West wants all decisions settled by simple majority vote. The Russians say in effect: "Specific issues must be decided only if the majority includes *all* of the atomic powers." Here the veto rears its ugly head.

Another unresolved point of conflict concerns the investigation of suspicious occurrences. The United States wants fully equipped teams to proceed immediately to the suspected locality. The U.S.S.R. wants *ad hoc* groups to go only after the control commission so directs.

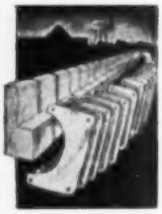
A further roadblock to agreement was erected in January when the United States released information about the Nevada underground tests performed the preceding October. These had yields of 100, 5000 and 23,000 tons TNT equivalent and were recorded on an extensive network of seismic stations. These records showed that the detection system considered last summer (180 stations, world-wide) would fail to detect many *underground* tests of 5000 tons equivalent—or at least fail to distinguish them from a minor earthquake. The western delegates believe that this new data should be incorporated with the old in an effort to devise a more adequate inspection network, but the Russians hold that the conclusions reached by the experts at last summer's meeting must remain the sole scientific basis of the Conference. The more recent announcement of the American tests in the stratosphere (which may or may not have been detected in Russia) has not simplified the matter.

On resumption of the recessed negotiations at Geneva April 13, President Eisenhower addressed Premier Khruschev as follows:

"The United States strongly seeks a lasting agreement for the discontinuance of nuclear weapons tests . . . [It] must, however, be subject to fully effective safeguards . . . and we believe that present proposals of the Soviet Union fall short of providing assurance of the type of effective control in which all parties can have confidence . . . If indeed the Soviet Union insists on the veto on the fact-finding activities of the control system for underground detonations, could we not put the agreement into effect in phases, beginning with a prohibition of nuclear weapons tests in the atmosphere up to 50 km. [altitude? This] would not require the automatic on-site inspection which has created the major stumbling block in the negotiations so far . . . If we could agree to this first – and I might add the most important – phase of a test suspension agreement, our negotiations could continue to explore with new hope the political and technical problems involved in extending the agreement as quickly as possible to cover all nuclear weapons testing . . ."

On April 25, Premier Khruschev demurred and emphasized again the need of an agreement to end *all* nuclear tests. "We shall punctually abide by the pledges, even if there is no control, because it is public opinion – the opinion of the people – that the Soviet Union values most of all."

*The first part of this page is formulated principally from "Roadblocks at Geneva", published in *Bulletin* of the Atomic Scientists, March 1959, p. 137.



Short Runs

Vacuum Furnace Features Quick Changeover

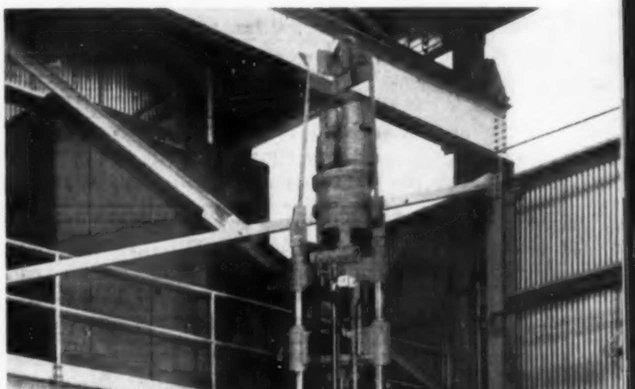
THE LATROBE STEEL Co. has a new consumable arc furnace. Designed by Lectromelt Div., McGraw-Edison Co., it is a simple unit, easy to operate. It is neat and compact, taking only 375 sq.ft. of floor space.

A unique feature is the quick changeover which is possible between melts. A two-man team can perform all operations since all controls, including those for the 10-ton overhead crane, are located at floor level. When a melt is finished, the crane lifts the superstructure, which contains the electrode feed mechanism, and sets it aside. Then, the water cooled copper crucible (with the remelted ingot) is raised from the well. After a clean crucible is installed, an electrode of the required composition is hung vertically in the superstructure. This setup is placed on raised legs (see Fig. 1), and the electrode is carefully lowered until it touches the bottom of the crucible. Then, the legs are retracted into the floor, the superstructure lowered, and the crucible tightly sealed to assure a continuous vacuum. Finally the arc is struck. The whole changeover takes about 20 min.

Other innovations are rectifier units built specifically for this unit. The 17,500-amp. rectifier consists of a simple, water cooled silicon unit, saturable reactor controlled. D-c. power bus connections have been kept as short as possible, and the water passing through the flexible conductors to the cathode connection also cools the electrode ram.

The furnace uses an electrode suspension mechanism which provides positive drive in both directions. Electrode drive design must satisfy two conflicting requirements. The first is sensitive, responsive, low-speed automatic regulation during melting to insure a short arc length. The second is high manual speed which is hundreds

Fig. 1 – Consumable Electrode Furnace Being Reloaded at Latrobe Steel Co. Two men can perform complete changeover in about 20 min.

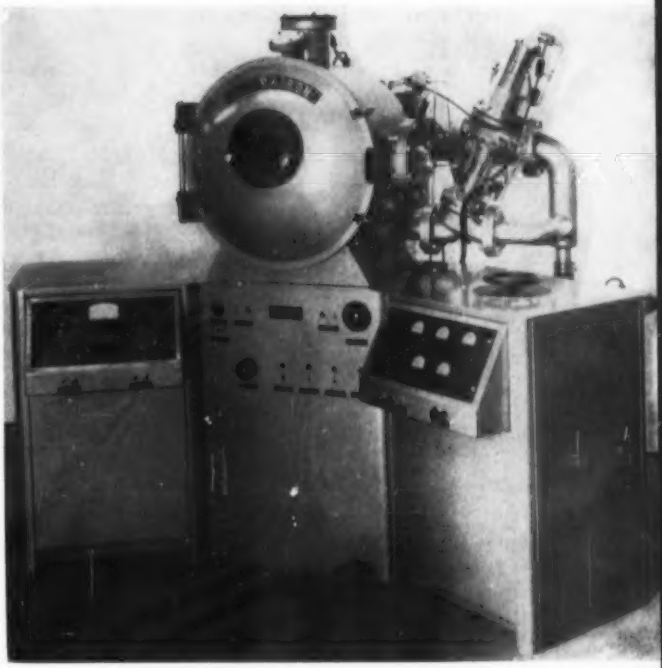


of times faster than melting speed. This helps keep downtime to a minimum. Lectromelt has designed a special differential gear device which satisfies both requirements. This provides an arc length control which has extraordinary accuracy and stability, combined with manual ram speeds of 5 to 6 ft. per min. The vacuum pump system has a capacity of 4500 cu.ft. per min., and has a blank-off pressure of under 5 microns.

Latrobe's furnace produces 20-in. diameter ingots which weigh 8500 lb., and capacity is estimated at 3000 tons per year. Sister units are planned for the future. According to the designers, only three men will be needed to operate two of these furnaces.

Welding With An Electron Beam

SHOWN in the photograph at right is a device called a "Beamatron" by its manufacturer, High Vacuum Equipment Corp. With it, tubes or parts up to 3⅛ in. in diameter and 10 ft. long can be welded by an electron beam in a high vacuum. Welds in reactive and refractory metals are enhanced considerably by this new welding technique.



Electron Beam Welder Showing Convenient Controls and 8-In. Diameter Port for Viewing Weld. Reactive and refractory metals are easily welded by this machine

Principles of Beam Welding

The electron beam welder is similar to an X-ray tube in that a cathode current source emits high-velocity electrons. These bombard the work to be welded, which is connected as the anode.

In the vacuum chamber, a suitable emitter (tungsten, for example) produces a cloud of electrons. This emitter, or filament, is housed within an electron gun structure, which serves as the control grid. A small sharp-edged hole is located on the side of the gun nearest the work. As electrons leave the gun through this hole, a high negative charge on the grid confines the electrons to produce a beam of small diameter.

For welding, the work is grounded (a safety feature), while the gun is at about 15,000 v. negative. To the electrons, the work appears positive, and they are attracted to the workpiece. A small electric current (less than 0.02 amp.) is therefore flowing to the work. The current alone is not enough to weld the metal. However, the high voltage accelerates the electrons so that they hit the work at up to 20% of the speed of light.

The individual electron, with its mass of 9.1×10^{-28} g. strikes the work and gives up its kinetic energy as heat. Mathematically, this is expressed as: Heat in calories per min. $= 1.4 \times 10^{-2}$ EI; where E = accelerating voltage and I = beam current.

When the beam of electrons is sharply focused for a high electron density, the heat input heats the work zone to the molten state very rapidly. The small heated zone, combined with the high heating rate, minimizes conduction losses. Silver and copper, for example, can be easily welded.

Since welding is done in a vacuum, there is no chance for contamination from an atmosphere. In fact, the beam cannot operate if the pressure is over 2×10^{-4} mm. of mercury. Thus, atmospheric impurity is automatically less than 1 ppm.

Nonmetallic inclusions are also removed from the fusion zone. Oxides, nitrides and carbides not destroyed by heating in vacuum are ionized by electron bombardment. As positive ions, they are lifted out of the melt and attracted to the negative grid of the electron gun. Most of these particles drop off when the gun is shut

down, or can be brushed off by the operator.

The two effects, prevention of oxide formation and removal of inclusions, combine to yield welds of excellent cleanliness. With the reactive metals (titanium, zirconium and vanadium) this cleanliness results in better corrosion resistance and a drastic lowering of brittleness and notch sensitivity in the weld and heat-affected zone. With the refractory metals (tungsten, tantalum, molybdenum, columbium and rhenium) welding is now possible as a fabrication technique; the increase in hardness usually associated with welding these metals is no longer so great.

Electron beam welding is a fail-safe operation. Because a high vacuum is necessary to support an effective beam, any pressure rise above the critical level will break down the beam. Other safety devices include overload relays and circuit breakers which protect high and low-voltage circuits, a vacuum switch which cuts off high voltage when the vacuum chamber is opened, and air-operated vacuum valves which are spring-loaded for fail-safe operation if air pressure fails.

Radio-Isotope Measuring System With Motorized Hopper at Rear. Plates pass through jaws of measuring unit, and correction signals are fed back to the hopper when variations occur

Radio-Isotopes Control Battery Plate Quality

Atomic radiation is now being used to minimize weight variations in battery plates. Installed by Industrial Nucleonics Corp. for the Price Battery Co., the AccuRay system, which employs beta and gamma rays from radioactive isotopes, determines plate weights accurately and at high speeds. This installation, the first in the automotive battery field, has resulted in more uniform battery performance and virtual elimination of substandard plates.

A battery is essentially an electrochemical apparatus; its quality is controlled to a large extent by the electrolyte and the plates. The electrolyte, a homogeneous liquid, is easy to control. However, plate weights are a function of several factors, and this makes control difficult. Since plates must be produced in large quantities at high speeds, it is physically impossible to weigh every single one mechanically. Yet 100% inspection is desirable; each variable is then subject to maximum control.

To solve this problem, the two companies cooperated in devising the system now used. The photograph shows the measurement system installed by Industrial Nucleonics. It measures the weight of each passing plate. When variations occur, appropriate signals are fed back to the motorized hopper in the rear. Built by Price, this hopper contains doctor blades controlled by hydraulic pistons which move according to the signals reaching it from the AccuRay setup. Auxiliary mechanisms monitor the system. The measuring unit withdraws from the line every 30 min. to standardize itself. If unable to measure accurately, the unit shuts itself down, and self-monitors the area of trouble. Control is permitted only within a narrow weight band; if upsets occur beyond this, an alarm rings, alerting the operator to take over. With the other fail-safe provisions also included, the machine can virtually run itself.

Measurement accuracy is within a gram per plate, and in a group of 250,000 plates the spread was 9.52 g. – 60% less than the spread under manual control. The periodic weight variation due to introducing a fresh batch of paste to the hopper has been almost completely eliminated, and unwanted density variations have been pinpointed for correction.

Ceramic Coatings Protect Heat Treated Parts

*By BRUCE LEONARD**

PARTS of 17-7 PH and other heat resistant alloys are now protected from oxidation during heat treatment by ceramic enamel coatings. Developed at Norair (formerly Northrop Aircraft Co.) for use in their operations, these coatings spall away as the part cools, leaving a bright, scale-free surface. This type of coating is now in regular use for 17-7 PH, 17-4, Type 321 and other stainless steels; coatings for titanium and some heat resistant alloys are well along in development.

The need for a protective coating was first felt when we tried to process 17-7 PH, a steel very likely to become embrittled in gas atmospheres. Scheduling difficulties arose because heat treatment had to be done by subcontractors; Norair did not have electric furnaces of the required size. However, we had large gas-fired furnaces available, and preferred to use them rather than depend on subcontractors. Protective coatings were the obvious answer, and ceramics offered a versatile material for them.

Concepts guiding their development are essentially the same for all coatings:

1. The enamel must fuse rapidly at the heat treatment temperature to seal out contaminants and at the same time be viscous enough to minimize flow.

2. The enamel must not react with the base metal or any of its constituents.

3. The enamel must remove any oxidation or scale which may have formed before fusion.

4. Coating adherence should be minimized.

*Ceramic Engineer, Norair Div., Northrop Corp., Hawthorne, Calif.

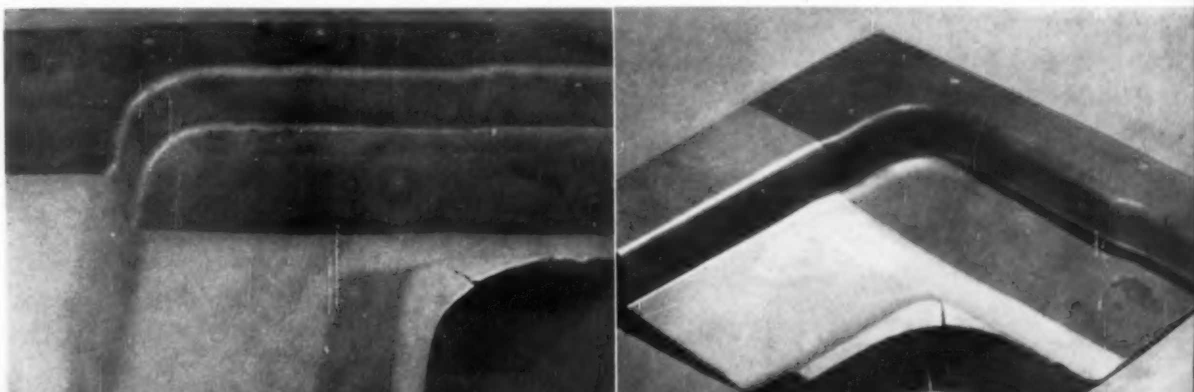
The latter, a very important feature, is achieved by avoiding the "adherence" oxides, developing the widest possible mismatching between expansion coefficients of metal and coating, and eliminating any surface roughness that may be present.

To use the coatings, the metal surface is normally cleaned by solvent or vapor degreasing; this is followed by alkaline cleaning. After coating (by dipping, spraying or brushing), the part is dried. At this stage, the coating is comparatively strong, thus offering protection from scratching during handling. The coated metal is charged into a neutral or oxidizing furnace – direct-fired or muffle – where the coatings fuse to a complex silicate or phosphate glass. Upon removal, the coating spalls off leaving the base metal bright and clean (see illustration). Handling techniques are the same as in the enameling industry – with one distinct difference. Workers must be protected from flying glass particles.

In developing these coatings, we faced some difficulties. Since toxic materials or materials which emitted toxic fumes upon thermal decomposition were to be avoided, enamels were limited to those with early fusion and high melt viscosities. Early work was done with a water-base system, but it soon became apparent that a stronger, less friable coating was required. After some experimentation, we found that a resin suspended in an organic solvent was fairly easy to apply and imparted good impact and abrasion resistance.

Development of "pop-off" protective coatings is still in its infancy. For one thing, self-spalling is still too dependent upon roughness of the metal surface. Thin gages also present special problems. There are too many different enamel compositions; the number now necessary will probably be reduced within the next few years. Despite these and other problems, ceramic coatings are expected to be an ever more useful feature of our heat treating operations.

Typical Part With Lower Portion Ceramic Coated (Left) Before and (Right) After Heat Treatment. Note that scale has been removed with the coating, leaving the part clean and bright



Pattern for Better Alloys

Vanadium-Alloys' new consumable electrode furnace operates under greater vacuum, promises higher quality for vacuum melted metals. (W18s, 1-73)

THE VACUUM ARC FURNACE shown on the opposite page bids to set new goals in quality for vacuum melted metals. Outstanding feature of the new consumable electrode furnace, which went into operation recently at Vanadium-Alloys Steel Corp., Latrobe, Pa., is its high-capacity pumping system designed to keep pressure levels below 1 micron. Production melts are being made with pressure of 0.5 of a micron and less – some 10 to 100 times greater than the vacuum in consumable electrode furnaces in operation today.

What This Means – The high vacuum protects the metal from air contamination and removes dissolved gases – hydrogen, oxygen and nitrogen. The low pressure and very high temperature in the arc (probably three times the melting point of the alloy) dissociate and remove nonmetallic inclusions. Vacuum arc remelting has a definite refining action on alloys prepared by air melting such as bearing steels (52100, M-2, M-50, M-52), ultra-high-strength missile and aircraft steels – for example, VascoJet 1000 – high-temperature alloys, reactive metals and other special compositions. Benefits of remelting cited by Vanadium-Alloys' metallurgists include:

- Improved cleanliness, lower gas content.
- Comparative freedom from center porosity and segregation.
- Improved hot working properties.
- Better mechanical properties at elevated and room temperatures. This is reflected in improved ductility and higher impact, fatigue, creep, and rupture strength.

Other Furnace Features – By pressing a single button the vacuum melting process begins – electronic controls turn the vacuum pumps on and off. An electronic system for control automatically maintains a short, consistent arc length which helps to keep a shallow arc pool – so important for homogeneous ingot build-up and flotation of impurities with the most efficient degassification. A remote optical system gives the furnace operator a continuous visual view (similar to television) of the arc and the molten pool. The new furnace unit produces ingot sizes ranging from 9 to 24 in. in diameter. The facility was designed by Consolidated Electrodynamics Corp. An article in a subsequent issue of *Metal Progress* will give details on furnace operation and quality of alloys after more production experience is available.

The 45-Ft. High Consumable Electrode Furnace Is Housed in a Building of Its Own

Welding Nuclear Power Equipment

*Reported by ROGER SUTTON**

Weldments for reactor systems must meet more rigid quality standards than are required in conventional power-plant applications. Materials and welding processes for fabricating equipment for nuclear systems were discussed at the recent A.W.S. meeting. (K-general, W11p; SS, Ni-b)

THE AMERICAN WELDING SOCIETY, at its annual meeting in Chicago (April 6 to 10), devoted two technical sessions to welding of equipment for nuclear power applications. The first session dealt with fabrication of major components of the Dresden Nuclear Power Station. This station is rated at 180,000 kw. electrical capacity, making it the largest all-nuclear power plant in this country. It is being designed and built by the General Electric Co. for Commonwealth Edison Co. and its affiliate, the Nuclear Power Group, Inc. This latter group consists of several electric power companies.

The Dresden Power Station, on the Illinois River some 50 miles southwest of Chicago, is a boiling water nuclear plant of the dual-cycle type. It produces primary steam at 1000 psi. and secondary steam at 500 psi. Equipment in the plant consists of such items as: (*a*) reactor pressure vessel and core assembly, (*b*) primary steam drum, (*c*) four secondary steam generators, (*d*) four reactor recirculating pumps, (*e*) emergency condenser, and (*f*) reactor coolant cleanup heat exchangers. All of this equipment was fabricated in accordance with the A.S.M.E. Boiler and Pressure Vessel Code and applicable cases. W. R. Smith of General Electric Co., San Jose, Calif., described the design, material selection and fabrication of these major items.

Fabricating Major Components

The reactor vessel is 12 ft. 2 in. inside diameter and is about 42 ft. high. It is fabricated of 5¼-in. thick manganese-molybdenum steel, SA 302 Grade B, and is internally clad with ⅜-in. thick Type 304 stainless steel. The heads and flanges were clad by welding, using the a-c. series submerged-arc process, with Type ER 312 (29% Cr, 9% Ni) wire for the first layer and Type ER 308 L wire for subsequent layers. Supporting structures for the internal core were fabricated of Type 405 stainless steel and welded with Type ER 312 electrodes. The reactor vessel weighs about 300 tons.

The primary steam drum is 7 ft. 10 in. inside diameter and 67 ft. long. It is also fabricated of 3¾-in. thick manganese-molybdenum steel, SA 302 Grade B, and is internally clad by welding as above with Type ER 308 L wire. Internals of the drum are fabricated of Type 304 stainless steel. This steam drum weighs about 182 tons.

"U" Bundle Has 1800 Tubes—The four secondary steam generators are of the drum type with a vertical "U" bundle. The primary fluid connections enter and leave the bottom head. The generators are fabricated of carbon-silicon steel, SA 212 Grade B. The primary side, consisting of the tube sheet and hemispherical head, is clad by welding, using the same technique as for the steam drum. The "U" bundle (1800 tubes) consists of Type 304 stainless welded tubing, ½ in. O.D. by 0.045 in. min. wall thickness, in accordance with specification SA 249. The tubes are welded to the cladding on the tube sheet by the inert-gas-shielded tungsten-arc process with a specially designed joint and a special torch.

The four recirculating pumps for the reactor are of the canned motor type. The casings are "cast weldments" of Type 316 stainless in accord with specification SA 351 Grade CF 8 M.

The emergency condenser is a heat exchanger which has the unique function of dissipating heat in the system in case of a rapid shutdown. It was prefabricated in sections and field erected.

*Supervisor, Stainless Steels, International Nickel Co., Inc., New York. Mr. Sutton was chairman of a technical session on Nuclear Power Equipment at the A.W.S. annual meeting.

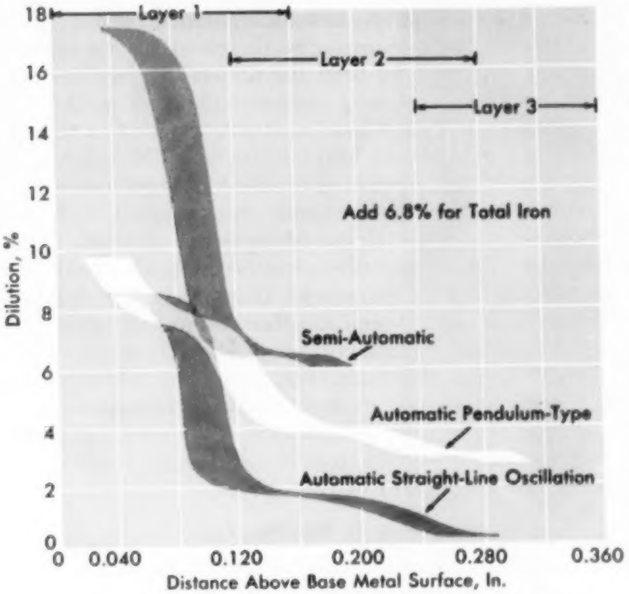


Fig. 1 – Steam Generators With Inconel Tubes Can Be Welded to the Required Quality Levels by Using a Controlled Inert-Gas Process and Inconel Filler Wire Modified With Titanium and Manganese. Chart shows dilution of Inconel overlays by steel base metal

the longitudinal seam. The pipe was rerolled hot, after welding, and air quenched on the rolls. Scale and foreign material were removed from the pipe surface by blasting and pickling treatments.

Welding and testing of the containment sphere was described by P. C. Arnold of the Chicago Bridge & Iron Co., who stressed the procedures used to guarantee impact values required by the A.S.M.E. Code. Many well-known electrodes would not give consistent impact properties in weld-metal; specially selected electrodes had to be utilized. Since field erection of the 1¼-in. plate made the standard preheat of 200 to 300° F. impractical, weldments were made at 30° F. to demonstrate that the mechanical properties were as good or better than those made under preheat conditions. It was also required that the containment vessel be tested by X-raying it throughout. The vessel ultimately was tested under a pressure of two atmospheres.

The shell is fabricated of carbon-silicon steel, SA 212 Grade B, welded with E 7018 electrodes. The primary side consists of two tube bundles fabricated of Type 304 stainless steel pipe and tubing, in accordance with specifications A 358 and A 213.

The reactor coolant cleanup system is made up of two regenerative and two nonregenerative exchangers fabricated of materials similar to those used in the steam generator.

The Piping System

Fabrication of the piping system was described by G. B. Grable and A. M. Croswell of Bechtel Corp. Emphasis was on Type 304 stainless steel piping which interconnects the major vessels in the nuclear portion of the system. This consists of 16-in. diameter risers and downcomers, 22-in. suction connections to pumps, 18-in. discharge piping, and smaller diameter piping in the system for cleanup of radioactive products.

Welded Pipe Is Used – The selection of seam welded stainless steel pipe for the large-diameter lines, in place of seamless pipe, and the use of cast stainless steel fittings instead of large forged fittings was considerably cheaper and saved manufacturing time. The large stainless pipe was hot formed from plate, followed by welding

The second session on nuclear equipment was devoted to problems of joining stainless steel and high-nickel alloys. The first paper, "Welding of Inconel for Nuclear Power Applications", was presented by W. F. Fragetta and G. R. Pease of International Nickel Co., Inc.

Overlays of defect-free Inconel on A 302 b steel were produced using an Inconel composition, modified with titanium and manganese. It was deposited by the inert-gas-shielded consummable-electrode process. The effects of preheat and postwelding treatments for stress-relief were established in anticipation of Code requirements for the A 302 b steel base.

Iron Pickup – In developing the Inconel overlay, considerable data were obtained on the distribution of iron in the weld metal. Graphical representation (Fig. 1) of iron dilution of weld deposits produced from the modified Inconel wire on steel showed a step-like gradient. A drop in the iron level of some 50 to 80% was noted across the first weld layer. From there on, the iron content levels off in transition areas between weld layers and decreases in somewhat smaller increments in subsequent layers. Control of dilution is closely associated with welding current and type of equipment used.

The procedures for overlaying were found to

be satisfactory for heavy section butt welds between steels overlaid with titanium-manganese modified Inconel wire and Type 308 stainless.

P. P. King and R. K. McGeary of Westinghouse Atomic Power Dept. described the braze bonding of stainless steel fuel elements. Cores of the Yankee Atomic Electric reactor and the Belgian thermal reactor use cylindrical uranium oxide pellets clad with stainless steel. The cladding holds back fission products and isolates the fuel from the primary coolant. Fuel elements for both reactor cores are composed of fuel tube clusters placed in square arrays.

Each fuel element for the Belgian reactor is 60 in. long and contains about 110 fuel tubes. Each Yankee fuel element is 90 in. long and contains some 300 fuel tubes. Brazing offered the only attractive method of holding these fuel tubes in position. Some of the requirements were: coolant flow must not be restricted; overall tolerances of straightness, size and tube spacing must be held to 0.025 in. or less; the brazing alloy must be corrosion resistant in high-temperature water; and finally, the brazing alloy must have a low nuclear cross section.

Plating Aids Brazing – All of the commercial brazing alloys were investigated. The only satisfactory ones were boron-free nickel-base alloys. The most favorable results were obtained with nickel phosphide eutectics. The most common one contains 11 to 12% phosphorus; it is available in powder form and is applied as a paste.

To eliminate center voids at the points of contact, the spacer tubes were given a coating of nickel-phosphorus alloy by the electroless plating method. This alloy contains about 7% phosphorus. After fitting-up, a suitable brazing alloy (as a paste) was added to the fuel elements as they were built up in the brazing fixture.

The fixture was fabricated to very close tolerances to insure contact between all fuel tubes. It was made of Type 304 stainless steel to match its expansion with that of the fuel element. Prototype fuel elements 60 in. long were brazed, sectioned, and then pulled apart to measure joint strength of full-size fuel bundles. Three hours at temperature gave brazed joints with strengths which equaled or exceeded that of the base metal so long as the tubes and spacers were not more than 0.002 in. apart. Micrographs show complete diffusion of brazing alloy into stainless steel.

Special Nickel-Molybdenum Alloy

G. M. Slaughter, P. Patriarca and R. E. Clausing of Oak Ridge National Laboratory discussed welding of nickel-molybdenum alloys. High-temperature nuclear reactors of the homogeneous type have been the subject of much investigation. Among systems with great potential are those in which fused salts are used as both fuel carrier and heat transfer fluid. Nickel-molybdenum alloys have excellent corrosion resistance to these environments; this, coupled with their superior elevated-temperature strength, makes them unusually attractive for this application.

Two commercial alloys, Hastelloy B (nickel-molybdenum) and Hastelloy W (nickel-molybdenum-chromium) were studied extensively as reactor construction materials. Although their compatibility with the liquid environments was adequate, both alloys were subject to age hardening at high temperature which resulted in a severe loss in ductility.

New Alloy Is Nonaging

Because of this, a major program was conducted by Oak Ridge's metallurgy division to study the aging parameters and to develop a modified alloy which did not exhibit this undesirable condition. Several modified compositions were studied, and one with the optimum combination of properties was designated INOR-8. This alloy has adequate corrosion resistance, satisfactory mechanical properties and does not exhibit appreciable aging characteristics. It is readily weldable – even where heavy sections are involved – thereby making it useful for the construction of conventional components.

Samples of welded joints of Hastelloy B, Hastelloy W, and INOR-8 were aged at 1100, 1200, 1300, 1500 and 1650° F. for up to 1000 hr. Hardness traverses were made to determine the influence of temperature and time upon relative age hardening characteristics of the weld metal, heat-affected zone, and the base plate. Early hardening of the two commercial alloys was noted, whereas INOR-8 alloy showed only a minor change in hardness – even after aging for extended periods.

Tensile specimens composed of all weld metal of these alloys were prepared and tested in the as-welded condition at room temperature and at 1200, 1300 and 1500° F. Several different heats of INOR-8 filler metal were studied in these tests to determine the influence of normal variations in chemical composition and to investigate the effects of minor alloying additions. The influence of the ingot melting procedure upon properties of welds deposited from the corresponding weld wire was also studied.

Tubes for Heat Exchangers Being Joined to a Tube Sheet by Inert-Gas Tungsten-Arc Welding. (Courtesy Griscom-Russell Co.)

New Developments in Welding Stainless Steels

*Reported by G. E. LINNERT**

Tests continue on an improved weld metal to replace Type 347 . . . Procedures are disclosed for welding AM-350 and AM-355 . . . Studies show that CO_2 welding of stainless may be undesirable for some applications because of carbon pickup. These were highlights of the stainless session at the recent A.W.S. meeting. (K-general; SS)

THE SESSION ON stainless steels held regularly by the American Welding Society at its annual meeting provides a yearly checkup on new developments in welding these metals. Three papers presented at the recent meeting in Chicago attracted a large audience. While the papers dealt with three different subjects, collectively they suggested that the welding metallurgist will have little rest ahead – with old products in need of improvement, new products lacking a welding dossier, and the unending appearance of new ideas to reduce costs.

*Supervising Research Welding Metallurgist, Research Laboratories, Armco Steel Corp., Baltimore, Md. Mr. Linnert was chairman of the session on welding stainless steels at the A.W.S. meeting.

Weld Metal to Replace Type 347

Weld metals of modified Type 347 were discussed by Thomas J. Moore, assistant director of research at Arcos Corp. Speaking on behalf of the Welding Research Council's Advisory Subcommittee on Welding Stainless Steels, Mr. Moore described the elevated-temperature properties of these weld metals as determined from a continuing series of studies sponsored by the AEC.

The aim of this subcommittee is to find a weld metal composition with none of the shortcomings which can appear in Type 347. This means it must offer: (*a*) freedom from hot cracking; (*b*) good corrosion resistance; (*c*) freedom from embrittlement during elevated-temperature service, and (*d*) suitable strength for use at elevated temperatures.

Modified Alloys — Attention now is centered upon two modified weld metals identified as Composition "C", fully austenitic 19-13 Cr-Ni plus columbium with 0.12% carbon, and Composition "H", the same basic alloy modified with 5% manganese. These appear to represent improved compositions that satisfy requirements for immunity to cracking, corrosion resistance, and freedom from embrittlement. Also included in the work for comparison are Composition "A", regular Type 347 containing ferrite, Composition "F", ferrite-containing Type 308 L, and a recently added "16-8-2" grade.

Mr. Moore described the most recent work which involved tensile tests at elevated temperatures, stress-rupture tests, and hot ductility studies made by E. F. Nippes at Rensselaer Polytechnic Institute. Significant differences in ductility at elevated temperatures were noted among the weld metals in these tests, which led Mr. Moore to speculate on whether particular combinations of strength and ductility provided some explanation for the behavior of weldments with respect to cracking during heat treatment. Further work on stress-rupture testing of these weld metals is under way.

Cr-Ni-Mo Hardenable Stainless Steel

Two high-alloy steels designated as AM-350 and AM-355 were surveyed for weldability by Robert H. Kaltenhauser, research metallurgist of Allegheny Ludlum Steel Corp. These steels were described as semi-austenitic stainless hardenable by low-temperature heat treatments to tensile strengths as high as 200,000 psi. Since these alloys do not air harden during welding, they are weldable by the same techniques and processes which are used for austenitic stainless steels.

Welded joints in AM-350 and AM-355 which are heat treated by the normal method for hardening have only about one half the yield strength of the hardened base metal. Metallographic examination revealed that the high temperature of welding increases the amount of free ferrite and stabilizes the austenite in the weld metal and in the heat-affected zones. Postweld annealing at 1710° F. gives a more complete transformation in the weld metal and in the heat-affected zones. According to Mr. Kaltenhauser, mechanical tests on welded material ranging in thickness from 0.024-in. strip to 1-in. plate have shown joint efficiencies of 90 to 100% over a range of tests from room temperature to 900° F.

Corrosion Resistance of CO_2 Welds

Two cost-conscious research men, B. E. Hopkinson and D. W. McDowell, Jr., of the International Nickel Co., have looked further into ways of reducing cost of shielding gas for welding stainless by the consumable electrode process. Aware that an earlier investigator had experimented with carbon dioxide shielding and found a small increase in carbon in the weld metal, Hopkinson and McDowell studied the corrosion resistance of welds made with CO_2 shielding.

Single and multipass deposits were laid down since it was thought that the multipass welds would be more susceptible to sensitization. Base metals of Type 304, 304 L, and 347 were employed with electrode wires of Type 308, 308 L, 310, 312, and 347. Welds shielded with regular argon gas were compared with those shielded by carbon dioxide.

Carbon Pickup — Chemical analyses indicated that carbon increases in the weld metal could occur up to 360% with CO_2 shielding (for Type 308 L). However, the highest level of carbon reached in any of the weld metals was in the order of 0.10 to 0.15%. The added carbon appeared to have two effects: *(a)* It reduced the amount of delta ferrite present, that is, if any was present in the argon shielded deposits, and *(b)* it resulted in sensitization in the earlier beads of multipass welds which leads to subsequent attack in corrosion tests. This means that CO_2 shielding gives a metallurgical condition which may be quite unfavorable depending upon the application of the stainless steel.

Personal Mention

David J. O'Neil and **Harold R. Potter** were recently named managers for the Carpenter Steel Co., Reading, Pa. Mr. O'Neil has been appointed Pacific regional manager, operating from Los Angeles, and Mr. Potter is now east central manager, working out of Cleveland.

Frank Fuchs and **Albert R. Fairchild** were recently promoted to senior staff engineers for the Western Electric Co., Winston-Salem, N. C.

Aldridge E. Hunt, Jr., has been promoted to district manager for the Hartford, Conn., and Providence, R. I., sales territories of the Carpenter Steel Co., Reading, Pa. Mr. Hunt, who came to Carpenter in 1957, was formerly product manager of mill products in Bridgeport, Conn.

William H. Gibson has joined Consolidated Metal Products' titanium division in Albany, N.Y., as casting metallurgist. He was formerly affiliated with the Green Island plant of Ford Motor Co. as quality control chemist-metallurgist and with the titanium and zirconium department of Allegheny Ludlum Steel Corp., Watervliet, N.Y,

W. W. Durand has been named chief metallurgist at the Crucible Steel Co. of America's Park works in Pittsburgh. He joined Crucible in 1937 as a metallurgical engineer at the Park works and since 1946 had been supervisor of the metallurgical laboratory.

Willard R. Pratt is now president of Vanguard Abrasive Corp., a subsidiary of National Grinding Wheel Co. of North Tonawanda, N. Y.

Joseph K. Seyler has been appointed superintendent, cold finishing department, at the Pittsburgh works of Jones & Laughlin Steel Corp. A member of the J&L staff since 1936, he last held the position of assistant superintendent of the cold finishing department in charge of the J&L Hazelwood operation.

Charles L. Meyers, Jr., , formerly a member of the technical staff of the Hughes product group, Semiconductor Research and Development Laboratory, Los Angeles, has accepted a post as senior scientist in the metallurgy and ceramics department of Lockheed Missiles and Space Div., Palo Alto, Calif.

R. M. Ailor is now supervisor, engineering chemical and metallurgical laboratories for the Fulton Sylphon Div. of Robertshaw-Fulton Controls Co., Knoxville, Tenn.

Laurence MacNaughton, Jr., , formerly research associate at Heppenstall Co., Pittsburgh, is currently a roll engineer for Midvale-Heppenstall Co., Philadelphia.

Ralph G. Dermott

As a further step in *Metal Progress'* editorial expansion, a new assistant editor – **Ralph G. Dermott** – joins the technical staff. Possessing a broad metallurgical background, Ralph has had experience with nonferrous alloys and in the application of aluminum casting alloys. As a member of the *Metal Progress* editorial team, he will pay special attention to developments in fabrication practices for ferrous and nonferrous metals.

Ralph enrolled in the State Teachers College at Lock Haven, Pa., in 1946, after his graduation from high school, but his education was interrupted two years later when he was called into the Navy. Following a five-year tour of duty as a flier in an antisubmarine squadron (he is currently active in the Naval Air Reserve as an aviator with rank of lieutenant), he decided to make metallurgy his career and transferred to Pennsylvania State University. While attending school there, he was very active in the Penn State Chapter and was an able reporter of chapter activities for *Metals Review*.

After graduation in 1956, he joined the American Brake Shoe Co. as assistant metallurgist studying the physical metallurgy of aluminum casting alloys, and a year later transferred to the light metals department as a project engineer, still working on aluminum casting alloys. Last March he resigned to become assistant research metallurgist at the Havens Laboratory of Bridgeport Brass Co., where he was engaged in research and development of wrought copper-base alloys until he came to *Metal Progress*.

Personals . . .

Bernard J. Alperin ⊕ has been named supervisor, inspection, of the Everett Foundries of General Electric Co. in Everett, Mass. Since 1957, Mr. Alperin has been development engineer for the applied research and development laboratory of the G.E. foundry department in Schenectady, N. Y.

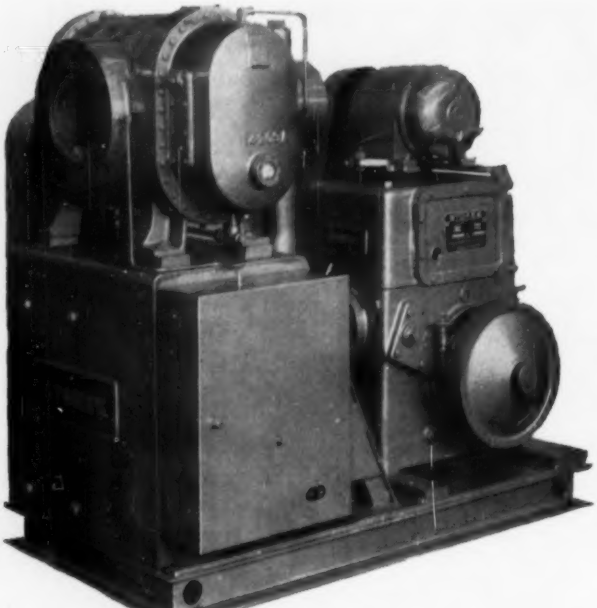
Richard W. Fountain ⊕ and **Milton Stern** ⊕ have been appointed technical supervisors in the metals research group of the technology department of Union Carbide Metals Co., Niagara Falls, N.Y. Prior to his appointment, Dr. Fountain held the position of section leader and research metallurgist in the metals research group while Dr. Stern was research metallurgist and section leader of corrosion and electrochemistry research.

Norman F. Spooner ⊕ has been promoted from supervisor to manager of research and development for Hoskins Mfg. Co., Detroit. A graduate of the University of Michigan, he has been affiliated with Hoskins for ten years.

Ralph W. Skerratt, Jr., ⊕, formerly executive vice-president, has been named president and general manager of the Falcon Foundry Co., Lowellville, Ohio. Mr. Skerratt was one of the founders of Falcon Foundry in 1953.

Robert Knight ⊕ has been named sales service manager for Johnston & Funk Metallurgical Corp., Wooster, Ohio, a subsidiary of Mallory-Sharon Metals Corp. Prior to joining the company, he was a contact metallurgist for the Crucible Steel Co. of America and subsequently supervisor of Crucible's production quality control laboratory.

Peter C. Rossin ⊕ and **William L. Bruckart** ⊕ have been assigned new posts at Universal-Cyclops Steel Corp., Bridgeville, Pa. Mr. Rossin, formerly technical director of the refractomet division, has been named general manager of the division, while Mr. Bruckart, formerly engaged in sales development for the company's refractory and reactive metal products, has been appointed manager of sales for the refractomet division.



Personals . . .

Leo M. Elijah has accepted a post as consultant on metals for George Sall Metals, Inc., Philadelphia, Pa. His technical background includes several years with Sylvania Electric Co., where he worked as senior engineer before taking on his new assignment, and Ford Motor Co. of Canada Ltd.

Robert D. Everett has been appointed general superintendent of the Sharon, Pa., works of National Malleable and Steel Castings Co. Since last December, he has been general superintendent of the Melrose Park (Ill.) Works of the company.

John Fuqua has been named chief plant metallurgist of Cooper Alloy Corp., Hillside, N.J. Before joining Cooper Alloy, he was employed as senior research metallurgist for the American Steel Foundries of East Chicago, Ind.

Gordon Graham, affiliated with the Southern Pipe Div. of U.S. Industries, Inc., Azusa, Calif., for the past six years, has been named plant manager, a newly created position.

C. J. McDonall was recently appointed district sales manager in New York for Vanadium-Alloys Steel Co., Latrobe, Pa. Formerly a sales engineer in the Springfield, Mass., district office, he will supervise sales and service in the metropolitan New York, New Jersey and southern Connecticut area. Associated with the company for eight years, Mr. McDonall is the immediate past chairman of the Hartford Chapter.

G. F. Norman, manager of the Montreal plant of Federated Metals Canada, Ltd., a division of American Smelting and Refining Co., has been promoted to vice-president and general manager of Federated Canada.

Charles D. Preusch has been appointed materials and process engineer for Crucible Steel Co. of America, Pittsburgh. Formerly chief metallurgist at the company's Spaulding Works in Harrison, N.J., he will now be responsible for providing company-wide standards of materials, practices and measurements in steelmaking operations.

Personals . . .

Martin J. Dempsey has been appointed product metallurgical engineer in the Crucible Steel Co. of America's technology department, where he will be responsible for the coordination and provision of technical service on toolsteel products. Formerly manager of the company's Detroit sales branch, he joined Crucible in 1941.

R. T. Eakin has been elected to fill a vacancy on the board of directors of Latrobe Steel Co., Latrobe, Pa. He joined the company last year as vice-president of operations, after more than 15 years' association with Allegheny Ludlum Steel Co.

Bernhard Blumenthal, an associate metallurgist on the staff of Argonne National Laboratory, Lemont, Ill., has been granted leave of absence to assist the Centre d'Étude de l'Energie Nucléaire in Belgium in plutonium research and development. Now assigned to the CEN laboratory in Mol, near Brussels, Dr. Blumenthal will guide the development of a metallurgical plutonium program and the building of a plutonium laboratory under a bilateral agreement between Belgium and the United States for the exchange of nuclear information.

Thomas J. McDonough, Jr., has joined Prentiss Wire Mills, Riverside-Alloy Metal Div., H. K. Porter Co., as assistant superintendent of the coarse wire department.

William A. Moore has left his position as pyrometry supervisor at the Utica Drop Forge & Tool Div., Kelsey-Hayes Co., Utica, N.Y., and is now attending Rensselaer Polytechnic Institute studying toward a degree in metallurgical engineering.

R. D. Halverstadt, formerly supervisor of the metal working laboratory in the jet engine department of General Electric Co., Evendale, Ohio, is now a consultant in the manufacturing services division for General Electric in New York.

Rupert Rudis has joined Aerojet-General Corp., Sacramento, Calif., as quality control senior engineer. He is head of material inspection section.

Personals . . .

John J. Collins has accepted a post as general manager of the new mining department of Revere Copper and Brass Inc., New York. This department has been created to develop ore sources. Mr. Collins has just returned to the United States from the London office of American Smelting and Refining Co. where for eight years he was the company's special representative in Europe and Africa, supervising the exploration of prospects in the Rhodesias, West and East Africa and the Portuguese colonies.

Richard J. Schemeck has joined the field sales and service organization of Rolock Inc., Fairfield, Conn. With headquarters in Skaneateles, N.Y., he will cover the upper New York state industrial area.

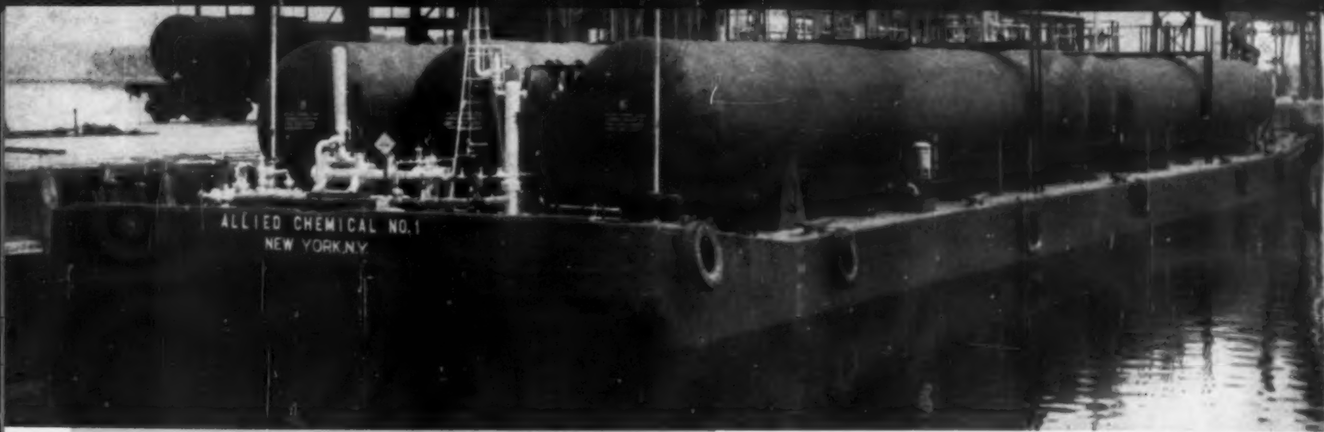
S. S. Gill is now working as area manager, foundries, at Hindustan Motors Ltd., Calcutta, India. For the past ten years, he was chief metallurgist for the company.

Alfred Siede has left a position as associate metallurgist with Armour Research Foundation, Chicago, to take up duties as a research engineer with Clearing Machine Corp., a division of U.S. Industries, Inc., Chicago.

R. P. Griffenhagen was recently appointed manager of the DC motor engineering department at the Buffalo, N.Y., motor and control division of Westinghouse Electric Corp. Past chairman of the Buffalo Chapter, he was manager of the materials and process section of the division before his promotion.

Roy E. Rohrabaugh has joined the processing engineering section of Mallory Sharon Metals Corp. as development engineer for special metals extrusions and tubings at the company's Niles, Ohio, plant. Prior to that time, he was supervising metallurgist, special metals research department, Allegheny Ludlum Steel Corp., Watervliet, N. Y.

Edwin C. Taylor has assumed the presidency of Taylor Contracting Corp., Richmond, Va., a company specializing in concrete paving and heavy construction in the east coast area.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Metals Engineering **Digest**

. . . Interpretative Reports of World-Wide Developments

Predicting Steelmaking Cost by Computer

Digest of "Predicting Minimum Materials Cost for Stainless Steel", by D. C. Hilty, R. W. Taylor and R. H. Gillespie. Paper presented at the A.I.M.E. Electric Furnace Conference, Dec. 5, 1958, Detroit.

USING LINEAR programing techniques with a digital computer, engineers at Union Carbide Corp. have studied material prices and steelmaking technology to select which combination of charge materials would give the lowest cost. Prices listed by over 30 different sources of chromium, iron and silicon were considered as well as the cost of oxygen and lime. In addition, the effect on cost of such melting variables as bath temperature before and after the oxygen blow, oxygen blowing rate, and slag basicity was investigated. A Type 430 stainless steel heat was programed, although the technique can be readily modified to include 200, 300 and other 400 series steels.

The linear program model assumed that a 70-ton furnace made Type 430 stainless steel to a specification of 0.08% C, 0.40% Si and 16.5% Cr. Carbon was assumed to be oxidized to 0.05% during the blow. Scrap availability was assumed to be 40%, of which one quarter (10% of the total chromium requirement of the steel) was suitable for back-charging as a cool-off addition following the blow. The results obtained relate to the scrap and ferro-alloy prices on Oct. 1, 1958, and to a generalized practice for a 70-ton furnace. Other prices and practices will alter these results.

Higher Temperatures Cut Costs

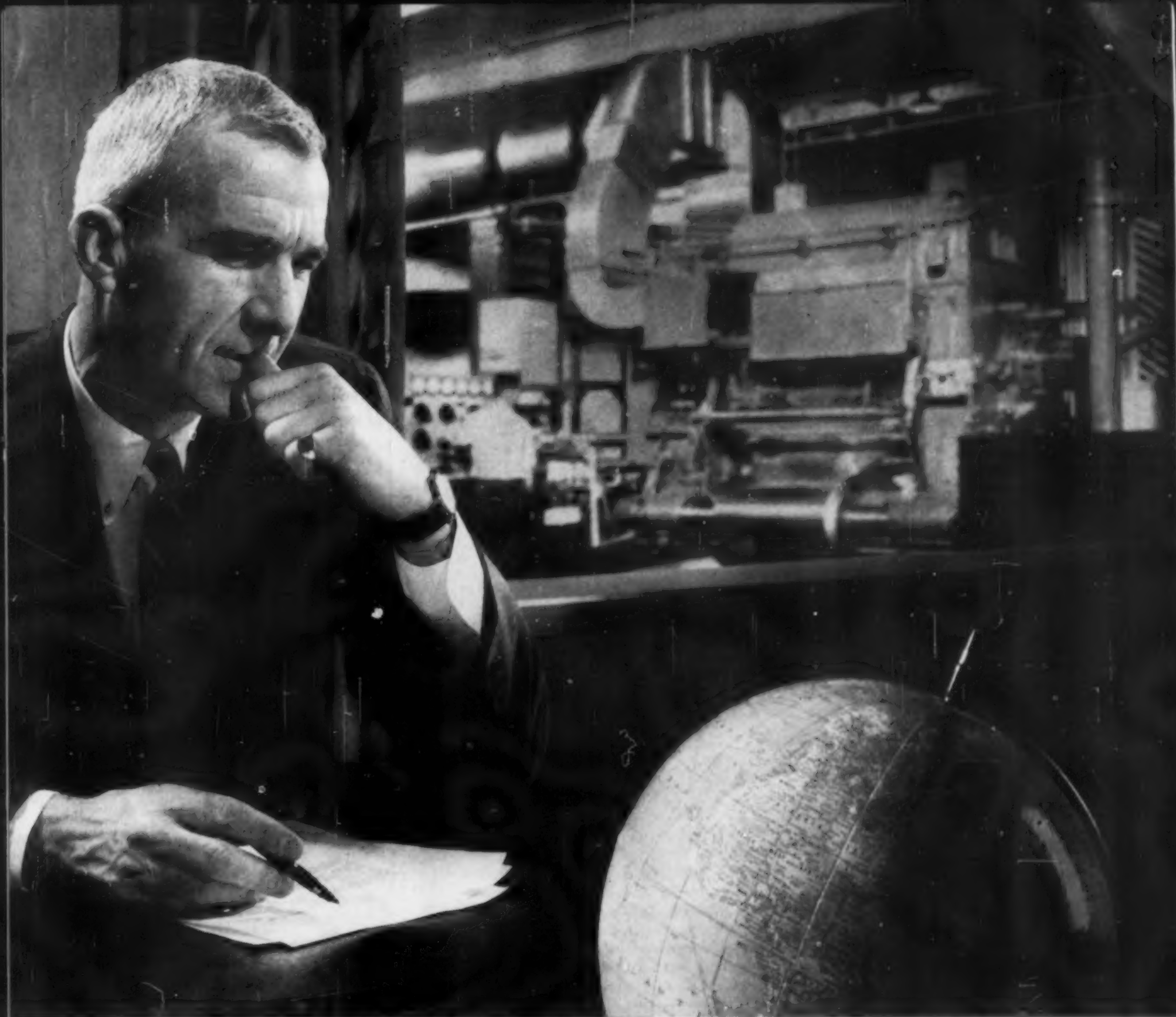
Cost reductions can be made by increasing the maximum temperature permitted at the end of the oxygen blow. At higher temperatures, more chromium can be charged as low-cost stainless scrap or refined ferrochrome. Naturally, these savings must be weighed against possible increased refractory consumption, a factor not considered by the computer. For example, 3400° F. for the end of the blow would not be practical because furnace refractories could be badly damaged. Figure 1 illustrates the cost trend with increasing end-of-blow temperatures.

Table I shows the effect of other operating changes, with end-of-blow temperature kept constant at 3315° F. Lowering bath temperature before the blow cuts costs because more low-cost ferrochrome can be used in the charge. Lowering the

Table I – Effect of Operating Changes On Costs

Conditions					
Temperature before O_2, °F.	2730	2910	2910	2910	2730
Temperature after O_2, °F.	3315	3315	3315	3315	3315
Slag basicity $\left(\frac{CaO+MgO}{SiO_2}\right)$	1.5	1.5	1.5	1.1	1.5
O_2 blow rate, cu.ft. per hr.★	500	500	1000	500	500
Melted before O_2, %	100	100	100	100	75
Charge					
Steel scrap, lb.★	870	893	886	883	869
Type 430 scrap, lb.★	628	618	610	625	633
Refined chromium, lb.★	191	114	99	111	118
Regular charge chromium, lb.★	—	—	—	—	86
Reduction					
Type 430 scrap, lb.★	209	206	203	208	211
55/24 ferrochrome-silicon, lb.★	168	99	51	96	184
Finishing					
Simplex No. 2, lb.★	21	137	186	145	—
Results					
Materials cost★	\$131.53	\$132.63	\$130.70	\$133.67	\$132.07
Slag volume, lb.★	280	180	101	151	330
Chromium in initial charge, %	12.13	9.99	9.60	10.00	12.43
Oxygen lanced, cu.ft.★	604	379	362	377	746
Lime, lb.★	147	92	55	77	164

★All values are units per net ton of top weight.



World-wide facilities contribute to the knowledge offered you by our engineers and representatives.

Steelmaking Cost . . .

basicity of the slag below 1.5 increases costs because more chromium is lost in the slag. On the other hand, increasing the oxygen blowing rate decreases costs because less chromium is oxidized during the blow. The additional effect of these variables on costs is relatively small.

Blending The Alloys

When it was assumed that 75% of the bath was melted at the start of oxygen injection, the computer selected a blend of regular charge ferrochrome and refined ferrochrome as the most economical charge addition. Blending was needed because two opposing reactions occurred. The higher silicon and carbon contents of regular ferrochrome provided some of the heat required for complete meltdown. On the other hand, carbon and silicon had to be limited because excessive amounts generate extremely high temperatures and cause severe furnace damage. Hence, the computer chose the best blend for the proper balance between silicon, carbon and chromium contents to satisfy the chemical and thermal requirements in the most economical way.

Although blending of alloys may be desirable for greatest economy under some operating conditions, it introduces problems in handling and stock maintenance that may be a nuisance from a melter's viewpoint. However, the example in Table I

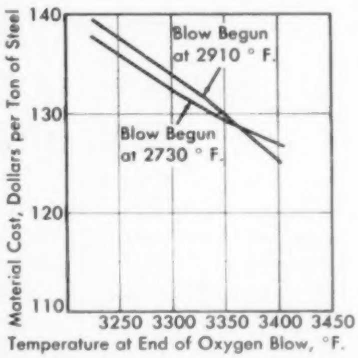


Fig. 1 — Effect of Temperature Before and After Oxygen Blow on Minimum Materials Costs. For these tests, the blow rate of this 70-ton furnace was 500 cu.ft. per hr. per net ton, and the basicity was 1.5

suggests that the computer technique can identify small changes in practice that will eliminate these problems. They may even improve the economics.

The relative slag volumes shown in the table, although somewhat idealized, are of considerable interest. They consider only the slag generated by the chemistry of the process, and make no allowance for slag-forming agents (other than silicon) that may be included in the meltdown charge. Nevertheless, their relation to each other is significant because larger slag volumes generally mean lower chromium recovery. These results confirm what operators have long suspected; namely, that the practice giving the lowest slag volume and the highest chromium recovery is not necessarily the most economical practice from an over-all materials viewpoint.

Other Possible Applications

This linear program model, as outlined here, applies to generalized practices. However, it can be expanded to include items pertaining to a particular shop or practice. The model can also estimate probable economic effects of changes in various melting conditions; this is perhaps its greatest advantage. Quick estimates of practice changes, which may be desirable because of price changes in raw material, are permitted. A complete solution to the program can be obtained with our computer in about 5 min. Hence, the melting operation can be simulated to study the influence of these operating variables with far greater speed and much less expense than conventional procedures.

It is also felt that this technique can interpret in practical terms the vast amount of fundamental data being uncovered on the physical chemistry of steelmaking. C.R.W.

Stress-Corrosion Fracture

Notes from papers presented at a technical conference on Physical Metallurgy of Stress-Corrosion Fracture, sponsored by A.I.M.E., Pittsburgh, April 1959.

"Relationship of Crystal Defects to Fracture", by J. J. Gilman, General Electric Research Laboratory, Schenectady, N.Y. – Crystal defects can cause cracking, although certain

Stress-Corrosion . . .

types of defects can also stop cracking. The defects referred to mainly concerned dislocations and their relation to fracture. Such dislocations can be nucleated by a crack, but some of them can inhibit crack motion while others lead to autocatalytic crack propagation.

"Effect of Elastic Strain on Electrode Potential of Metals", by Ling Yang, G. T. Horne and G. M. Pound, Carnegie Institute of Technology – Theoretical calculations can explain why elastic tension shifts the electrode potential of a metal in the noble direction, while the reverse occurs under compression. The only possible thermodynamic explanation lies in the transport of interstitial impurities between the metal electrode and the electrolyte; hydrogen is thought to be a likely impurity. Experimental results show that thermodynamics do not predict the propensity of a metal to corrode under the conditions mentioned. Corrosion rates, however, are thought to be capable of being influenced by extremely high stresses, such as might exist at line imperfections.

"Crack Propagation During Stress-Corrosion", by C. Edeleanu, Tube Investments Co., Hinxton, England – Microscopic observations were made during cracking of single crystals of alpha brass in ammonia at room temperature, and both plate and motion photographs were taken. After an induction period, cracks start and propagate in a direction roughly perpendicular to the applied stress. Ahead of the tip of a crack a very faint "ghost" crack occurs which appears at once in its entirety, and widening occurs gradually. It was postulated that cracks progress in short, repetitive steps of brittle fracture, and that corrosion assists in the initiation of cleavage. Short-range order and the resulting slowing down effect on dislocation movement are thought to contribute to the running of brittle cracks in ductile materials. It was concluded that crack propagation consists of alternating slow chemical and rapid mechanical stages.

"Role of Corrosion Products in Crack Propagation in Austenitic Stainless Steel – Electron Microscope Studies", by N. A. Nielsen, E.

(*Continued on p.* 149A)

Stress-Corrosion . . .

I. du Pont de Nemours & Co., Inc., Wilmington, Del. – Transgranular cracks in austenitic stainless steel in magnesium chloride propagate by repeated releasing of strain energy. Every time sufficient pressure is exerted by the solid corrosion product inside a crack, a threshold stress is exceeded and crack growth is triggered. Corrosion products, being extremely thin, are not easily seen. Treatment with bromine-methanol solutions revealed their existence when specimens were viewed under the electron microscope, and they were described as "tongue", "fan" and "fringe"-shaped.

The composition of the corrosion products was found to be that of mixed, hydrated oxides, enriched in chromium. Oxide film replicas indicated that cracks consist of grooves, below which narrower crevices, filled with oxide, extend into the metal; the thin part of the crevice is a few hundred angstroms thick. Fracture-face studies showed that fracture is accompanied by minimal corrosion, and that cracking prefers the (111) plane.

"Effect of Stress and Environment on Microtopology of the Corrosion Product", by E. A. Gulbransen and T. P. Copan, Westinghouse Research Laboratories, Pittsburgh – Electron microscope studies were made on the shape and structure of oxides formed when metals were reacted at 300 to 800° C. in atmospheres containing different amounts of oxygen and water vapor. Samples were tested with and without stress. Transmission studies showed crystals in the form of whiskers, round platelets, blade-shaped platelets, serrated platelets and heavy needles. Whiskers about 200 A in diameter and up to 500,000 A formed when heating iron at 500° C. in oxygen.

In the presence of stress or water vapor, the corrosion product occurred as platelets about 100 A thick, up to 100,000 A high and 250,000 A wide. Precipitates in the metal affect the shape of crystals, as do stress, strain and water vapor. It was proposed that localized reaction in the vapor phase causes the unusual structures, and that pits and trenches in the metal substrate could result. The sites for localized reaction may be edges, dislocations or

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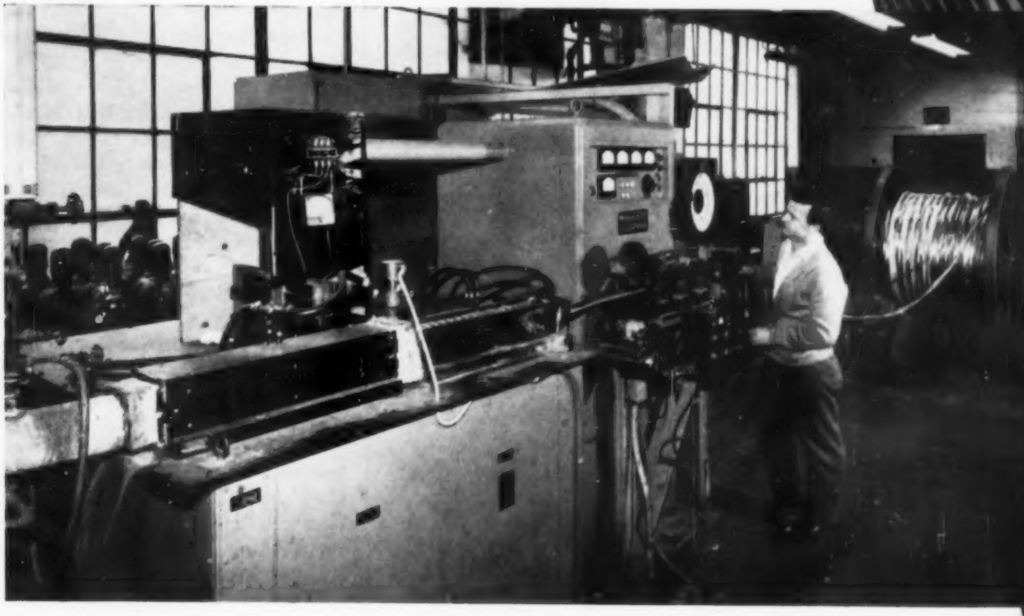

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Stress-Corrosion . . .

other defects which could align themselves under stress in some alloys. It is thought that these nucleation sites can be the same as those which cause crack initiation in liquid media.

"Metallographic and Crystallographic Examination of Stress-Corrosion Cracks in Austenitic Cr-Ni Steels", by J. G. Hines and R. W. Hugill, Imperial Chemical Industries Ltd., Billingham, England – Stress-corrosion cracks develop in austenitic steels in two stages: First, fine cracks form which spread sideways faster than inward into the metal; next, larger open cracks, extensively branched, form from fine cracks after yielding ahead of the crack. Three-dimensional studies were done by repeated sectioning in order to follow crack development.

Changes in crack direction occur within grains as well as grain boundaries. In softened materials cracks do not follow single crystallographic planes for any considerable distance, and the path of a stress-corrosion crack is determined mainly by the stress distribution near the advancing edge. No absolute mechanism for cracking was shown in the tests, although they can all be explained in terms of an electrochemical mechanism.

"Stress-Corrosion of Single Crystals of Stainless Steel", by H. W. Paxton, R. E. Reed and R. D. Legget, Carnegie Institute of Technology – Single crystals of stainless steel were grown from the melt in an inert gas atmosphere. Annealed specimens were tested in boiling magnesium chloride solution, and the specific specimen referred to was immersed for 120 hr. at 132° C. while stressed at 7200 psi. – an initial load of 9300 psi. had caused visible Lüder's bands. Pits were found at or near the edges of the samples with cracks issuing from some but not all of them; some cracks were not obviously associated with pitting. It was not certain that cracks preferred certain crystallographic planes. At the tip of cracks, slip occurred on a system different to that found in the same general area, indicating macroscopic plastic flow.

"Electrochemical Mechanism of Stress-Corrosion Cracking of Mild Steel", by H. J. Engell and A. Baumel, Max-Planck-Institut für Eisenforschung, Düsseldorf, Germany – Potentiostatic test results were reported on iron exposed to hot salt solutions. Passivity is found at low potentials in concentrated nitrate or hydroxide solutions (which give rise to stress-corrosion), but not in solutions such as chloride sulphate and perchlorate (which do not give cracking). Passivity was thus associated with stress-corrosion. Grain-boundary attack in mild steel could be caused by both stress and anodic polarization, the one capable of replacing the other.

Stress enlarges the potential region within which local electrochemical attack is possible. Anodic polarization or oxidizing agents, such as dichromate and nitrite, shortened the life of stressed specimens. Crack propagation occurs in sudden steps as shown in jumps in the potential-time and extension-time curves. Stress in excess of the yield stress causes strain, slip and film disrup-

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tion, which influence local electrode potentials.

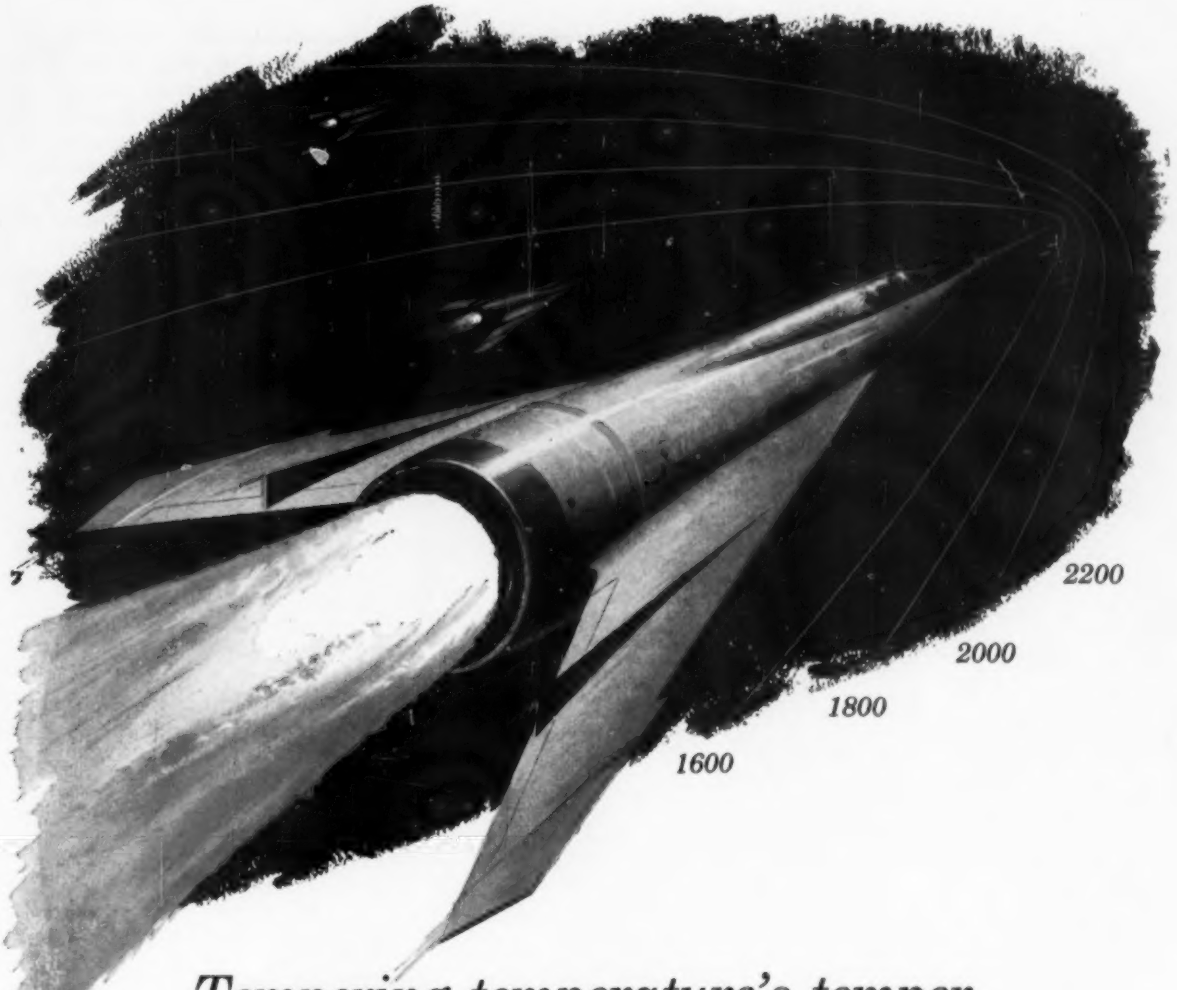
"Dependance of Stress-Corrosion Cracking Susceptibility on Age Hardening in a Copper-Nickel-Silicon Alloy", by W. D. Robertson, Yale University, E. G. Grenier, W. H. Davenport and V. F. Nole, Chase Brass and Copper Co., New Haven, Conn. – The susceptibility of a copper alloy with 1.9% Ni and 0.6% Si to stress-corrosion cracking in ammonia was studied. Without deformation, the failure is intergranular and sometimes observed at coherent twin boundaries. Transgranular cracking occurs in plastically deformed alloys and apparently follows deformation bands. In the latter instance, the rate of penetration by corrosion decreases as the number of attacked sites increases.

Stresses which could be tolerated for 1000 hr. showed that there was an absolute decrease in susceptibility to stress-corrosion as the amount of deformation, preceding aging, increased. Deformation after aging has a similar but smaller effect. The results were explained in terms of precipitation variables and their influence on structural paths which were attacked.

"Stress-Corrosion Cracking in Austenitic Stainless Steels in High-Temperature Chloride Waters", by W. M. Kirk, F. H. Beck and M. G. Fontana, Ohio State University – Tests were conducted in autoclaves at high temperature, using Types 347 and 316 stainless steel. Lowering of the temperature increases the time before cracking starts in dilute sodium chloride solutions. Under conditions of vapor condensation, there is no difference in cracking of the two steels. The initial pH of the solution also affects corrosion, and intermittent wetting and drying give results normally associated with higher chloride contents.

Cracks always originate at pits, the geometry of which determines whether cracks can be initiated. It was postulated that crack propagation takes place in a series of short bursts, and the base of a crack becomes sharp so that high strain energy maintains the progression of a crack.

"Cracking and Fracture of Steel in the Presence of Hydrogen – Cor-



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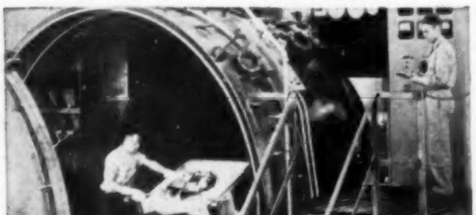

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Stress-Corrosion . . .

rosion Under Stress in the Presence of Moist Hydrogen Sulfide", by P. G. Bastien, École Centrale des Arts et Manufactures, Paris, France – Hydrogen embrittlement results when stressed steel is placed in moist hydrogen sulfide. The effect of hydrogen does not become apparent as long as the stress is in the elastic region, except in the case of delayed fracture. Embrittlement appears only in the presence of plastic strain. The susceptibility of a steel to hydrogen embrittlement depends on its microstructure; fine spheroidal carbide dispersions in a ferrite matrix are least susceptible. Hydrogen appears preferentially in the (112) plane of steel with an alpha structure, and in the tetrahedral positions in body-centered cubic ferrite.

A mechanism was proposed for embrittlement, whereby protons are entrained by dislocations set in motion during slipping on the (112) planes. A temporary pressure increase is caused by the accumulation of protons in lattice defects, such as dislocation groups. Delayed fracture may occur below the elastic limit when unstable dislocations are set in motion under stress.

"Effect of Composition on Stress-Corrosion Cracking of Some Alloys Containing Nickel", by H. R. Copson, International Nickel Co., Inc., New York–Specimens of many alloys were tested in boiling magnesium chloride at stress levels of 33,000 and 45,000 psi. Nickel contents ranged from 8 to 80%; specimens were in wire form, annealed, partially hardened or fully hardened. Time for failure increased with increasing nickel content and immunity was reached at 45 to 50% Ni. Electrochemical data were given to support the idea that nickel is the noble constituent in stainless steel.

"Initiation and Propagation of Cracks in the Stress-Corrosion of Alpha Brass and Similar Alloys", by A. J. Forty, University of Bristol, England – If plastic deformation involves the movement of dislocations, then, for a truly brittle fracture to proceed, the velocity of a crack must exceed that with which dislocations move away from its tip. To have a slow crack, therefore, dislocations must be restricted. Cracking occurs between neighboring pre-existing slipbands; the material between these slipbands is sufficiently hardened to support brittle fracture, while the slipbands themselves are softer and capable of stopping a crack. This explains why a crack runs only for a short distance at a time.

Cracks are re-originated at soft regions by embrittlement or selective corrosion, and this low stage in the process is rate-determining. Short-range ordering of the structure into phase domains is considered to be the most likely structural factor influencing the propagation of slow cleavage cracks. In the instance of single crystals, it is thought that the surface becomes embrittled by the chemical environment, sufficiently restricting plastic deformation to cause a crack to start. In polycrystalline materials, cracks at grain boundaries could perhaps start as a result of inhomogeneous shear.

"Stress-Corrosion Cracking in

Stress-Corrosion . . .

Low-Carbon Steel", by H. L. Logan, National Bureau of Standards, Washington, D.C. – The stress-corrosion of low-carbon and decarburized steels was investigated in boiling 20% ammonium nitrate solution. All cracking was intercrystalline. Extensive plastic deformation preceded cracking in fine-grained materials, while such deformation was less in large-grained samples, or those which were made anodic by applied currents. Anodic currents also resulted in failure in shorter time. Grain boundaries which appeared susceptible to cracking were those between grains where high energy conditions could be expected. Intercrystalline cracking was explained in terms of the film-rupture theory.

DANIEL VAN ROOYEN

Electrolytic Recovery of Manganese

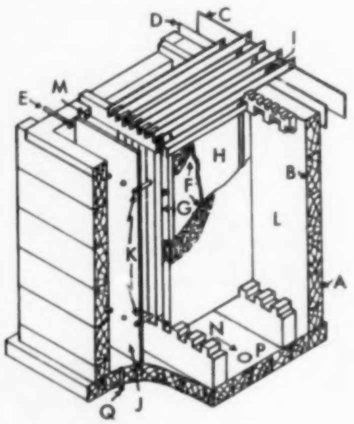
Digest of "A New Commercial Process for Electrowinning Manganese", by M. C. Carosella and R. M. Fowler, *Journal*, Electrochemical Society. Vol. 104, June 1957, p. 352-356.

ELECTROLYTIC RECOVERY of manganese from aqueous solutions has been under investigation for over 20 years, with varying degrees of technical success and economic feasibility. The U. S. Bureau of Mines and Electro Metallurgical Co. have been responsible for most of the developmental work from the laboratory to pilot plant to the commercial level.

About two years ago, Electromet perfected an improved electrolytic cell for manganese recovery, shown on p. 158. Basically, it is a rectangular tank *A*, with a lead lining, *B; C* and *D* are the cathode and anode busbars connected, respectively, to nine Hastelloy alloy cathodes, *H*, and to ten anodes, *I*, of 99% lead and 1% silver alloy. Feed is introduced at *E* into the catholyte header, *J*, which supplies the individual frames, *G*, the latter being covered with canvas or synthetic fiber diaphragms, *F*. Two outlets, *K*, are provided on each cathode frame for circulating catholyte to the common header. (*Cont'd on p.* 158)

Electrolytic Recovery . . .

Hydrogen generated at the cathodes, *H*, acts as a gas lift to cause the catholyte to circulate freely, resulting in a uniform concentration of manganese and hydrogen ions (pH) in all catholyte compartments. The solution passes through the diaphragms, *F*, into the anolyte compartment, *L*, while the spent anolyte overflows from the cell at *M*. Anode sludge formed during electrolysis falls freely into the bottom of the anolyte chamber which is sloped to allow flushing the sludge through a valve, *P*, without disassembling the cell. The catholyte header can be flushed readily, when required, through outlet *Q*.



Improved Electrolytic Cell for Recovery of Manganese From Aqueous Solution. Identification of components is given in text

Cathodes for deposition of manganese must be chemically inert, with a surface to which the electrodeposit adheres firmly but can be stripped by flexing or hammering. Various corrosion resistant alloys were tried in pilot cells. Cathodes of Hastelloy alloys performed better than those of stainless steel, being more corrosion resistant and requiring only infrequent polishing. Metal which did not strip from the Hastelloy cathode could be dissolved in the anolyte without destroying the polished surface.

In the latest commercial plant, the source of manganese is a high-manganese slag produced by smelting manganese ore in a submerged arc furnace with coke and flux. The slag is milled to −200 mesh by dry

Electrolytic Recovery ...

grinding, leached to a pH of 4.4 with anolyte and make-up sulphuric acid. The resulting slurry next is treated with gaseous ammonia to a pH of 6.6 to precipitate most of the impurities.

Neutralized slurry is filtered and the residue washed with water to recover the soluble manganese. The filtrate and wash water are treated with a small amount of hydrogen peroxide to oxidize and precipitate the residual iron. The precipitate then is filtered from the solution which is finally pumped to a cell-feed storage tank. Sulphur dioxide is added to the solution before it enters the cell circuit. Anolyte produced in the cells is returned to the leaching circuit.

Hastelloy Alloy C cathodes, 42 × 24 in. by 16 gage, are removed from the cells on a 72-hr. schedule. They are first dipped in dilute sodium bichromate to prevent darkening of the metal surface, then washed to remove soluble salts, and dried. Brittle deposits are stripped with the aid of a rubber mallet. Then the cathodes are soaked in anolyte to remove any residual deposit, and after washing with detergent and rinsing are ready to be returned to the cells.

Stripped manganese is either packed in drums for shipment or loaded in stainless steel cans which are placed in an electric oven to remove any hydrogen. The metal is of consistently high quality, residual metallics being less than 10 ppm. each, with the exception of lead, silicon, calcium and magnesium, which may run up to 20 ppm.

Arthur H. Allen

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AMCHEM Information Bulletin

CHEMICAL PREPAINT TREATMENTS FOR METAL SURFACES

What they do, the types available, how they are applied

By J. H. GEYER, Manager, Product Development Dept., AMCHEM PRODUCTS, INC.

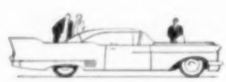
Paint systems have been steadily improved in an effort to produce more decorative, easier-to-apply, and more corrosion-resistant films. The ability, however, of any paint film to perform its predetermined functions cannot be fully utilized without properly preparing the metal surface.

Chemical *prepaint* treatments are designed to do four jobs and do them well. First, they remove organic soils, shop dirt, scale, and rust or corrosion products from the metal surface. Second, they provide surfaces that are completely compatible with subsequent paint films. Third, they produce a *tooth* that promotes good paint film adhesion. Fourth, they effectively prevent underpaint corrosion growth after any breakthrough in the paint film.

Basically, there are four types of chemical prepaint treatments—phosphoric acid, iron phosphate, zinc phosphate, and amorphous phosphate or chromate.

Phosphoric Acid—Phosphoric acid cleaner combination materials are an example of economical chemical prepaint treatments. Amchem Deoxidine is such a material. It removes organic soils, rust, scale and contaminating elements from the metal surface. It also produces a light etch on steel, aluminum or zinc surfaces which considerably aids in increasing paint adhesion. It does not, however, form an actual coating on the metal surface. Any breakthrough in the subsequent paint film will permit underfilm corrosion to proceed. Grades of Deoxidine are available for application by brush or swab, hot and cold dip, or hot spray.

Iron Phosphate—Iron phosphating processes are extensively used in the chemical prepaint treatment of appliances—water heater shells, ranges, washers, dryers and other *white lines*. These processes will produce excellent paint-bonding films on the metal and retard or prevent underpaint corrosion. Duridine, Amchem's iron phosphating process, is a combination organic soil cleaner and iron phosphate coating material. Both the cleaning and coating operations take place in the same bath. Duridine and other iron phosphates do not lend themselves to brush-on application, are primarily designed for spray type equipment of four or five stages. But several dip installations are successfully operating today by inclusion of an alkali precleaning stage.



Zinc Phosphate—Amchem Granodine is an example of zinc phosphating, the type now being used to treat steel in the automotive industry, and predominantly specified for steel ordnance and military items. This process forms a coating which offers the ultimate in paint adhesion promotion and vastly augments the corrosion resistance of subsequent paint films. Zinc phosphate materials are extremely flexible as to method of application—can be applied by brush, dip or automatic spray equipment. In a typical dip or power spray system, the stages would be alkali clean, water rinse, zinc phosphate treatment, water rinse, acidulated final rinse. If the metal has considerable areas of rust or scale, an acid pickle is advisable following the alkali cleaning stage.

On zinc surfaces, the zinc phosphates perform a rather unique function. They act as a barrier against chemical reaction between the applied paint film and the zinc surface. This effectively prevents blistering of the paint and early breakdown of the film. This is in addition, of course, to the improvement of paint adhesion and the retarding of underpaint corrosion. Amchem Lithoform is specially designed for use over zinc surfaces and finds wide application as a prepaint treatment for ornamental zinc die castings, refrigerator liners, and on most galvanized work requiring painted finishes.

Amorphous Phosphate and Chromate—These coatings are the films produced by the Amchem Alodine processes and similar ones on aluminum surfaces. They have met with wide acceptance in the prepaint treatment of venetian blind strips, refrigerator liners, aluminum heat transfer units, aircraft sheet metal assemblies, and many other items fabricated from aluminum. The various coatings provide an excellent film for the promotion of paint adhesion and effectively prevent underfilm corrosion. As in the case of zinc, aluminum exhibits a tendency to chemically react with some paint systems. The Alodine processes develop a barrier film between the paint and the aluminum surfaces which prevents this reaction. The Alodines are extremely versatile materials that can be applied to aluminum surfaces by brush, hand spray, dipping, or mechanical spraying. Brush application is particularly well adapted to the processing of parts too large for simple dip systems or in manufacturing operations that do not warrant a tank setup. In dip or spray application, the system usually consists of an alkaline preclean, a water rinse, the Alodine treatment, a water rinse, and an acidulated final rinse. Where the surface is heavily oxidized, a deoxidizer in the line is needed.

For more complete information about any one or all of these chemical conversion coatings, contact an Amchem sales representative or write us at Ambler 23, Pa.

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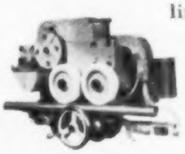


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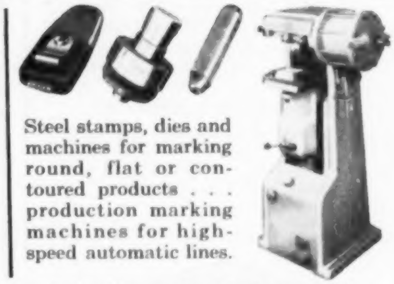

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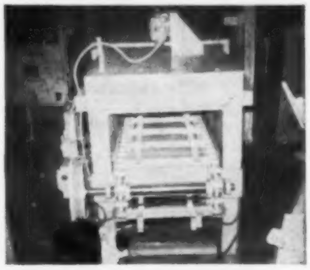

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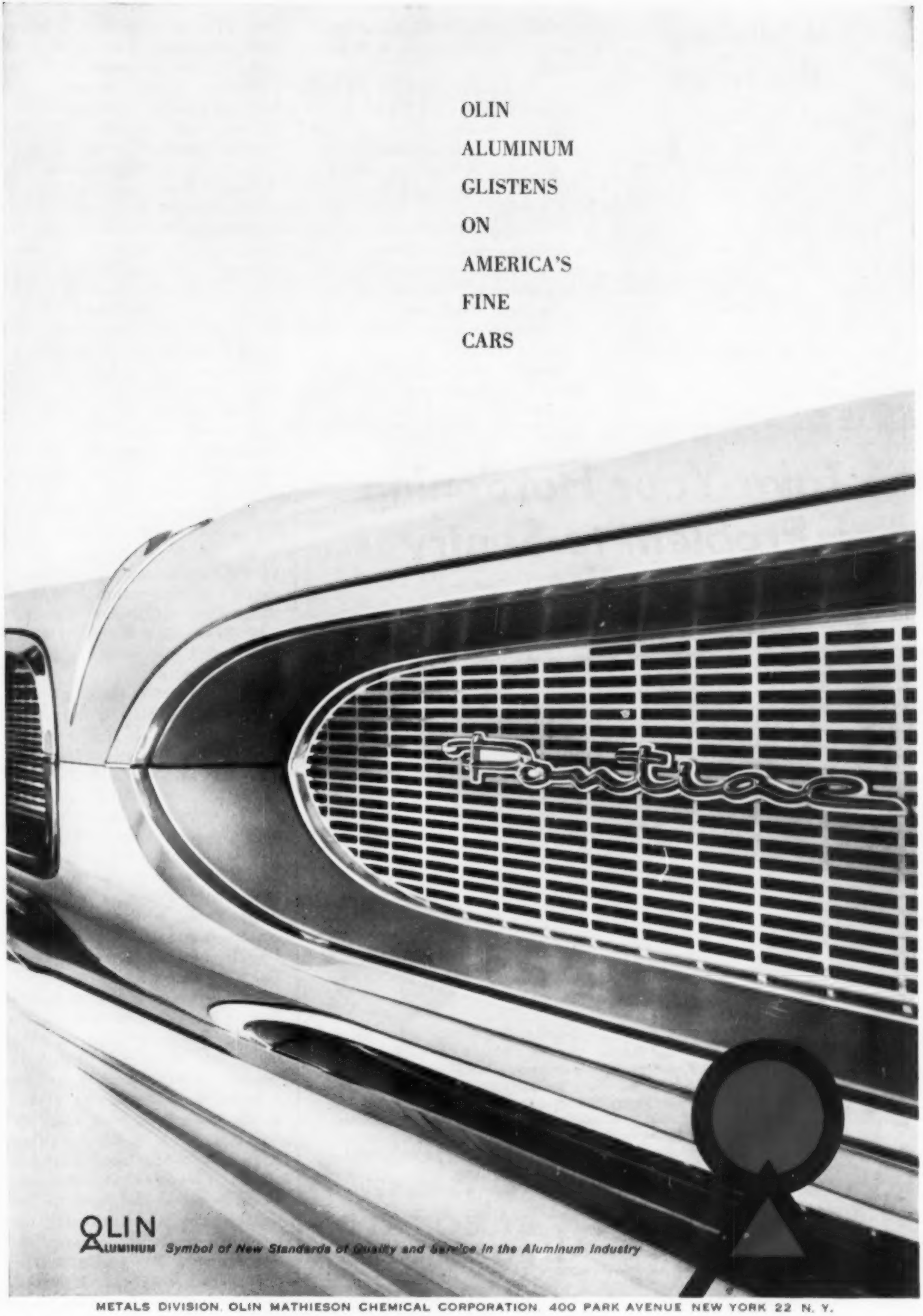

METALS DIVISION, OLIN MATHIESON CHEMICAL CORPORATION, 400 PARK AVENUE NEW YORK 22 N. Y.

A Self-Lining Blast Furnace

Digest of "Proposal for a Self-Lining Blast Furnace", by W. A. Archibald, T. P. Brown and L. A. Leonard, *Journal*, Iron and Steel Institute, Vol. 187, September 1957, p. 32-45.

CONVENTIONAL blast furnaces are lined with refractory brick 3 to 5 ft. thick in areas above the hearth. Recently the bosh and hearth sections have used carbon blocks, especially in England. As this paper is concerned primarily with the sections above the mantle, only this region will be discussed.

The refractory brick gradually and unevenly wears away due to three primary causes:

1. Abrasive action of the descending materials.
2. Shot-blasting effect of the ascending dust laden gases.
3. Fusion action in zones above 1800° F. in the region just above the mantle.

The downward movement of the solid charge and the upward flow of the gases give rise to the principal wearing forces. The extent of wear under these conditions depends on the abrasive resistance of the refractory in service.

Abrasion tests carried out in the laboratory on cold new bricks provide little indication of their potential performance, because in vital areas in the stack and bosh the properties of the refractory are seriously impaired by slag attack and disintegration. Elsewhere in the furnace, moderate wear or even considerable growth are evident, all in face of these scouring actions.

The amount of abrasive wear occurring at different positions in the furnace is diminished by the presence of lubricating liquids. The effectiveness of this depends on the quantity and the nature of the liquids concerned. High in the dry zones of the furnace severe abrasive wear, even of sound bricks, is commonly encountered.

Wear, hanging and scaffolds are complicated mineralogically and chemically but, except for abrasive wear in the top dry zone, they are all caused by simple phase changes in the charge and in the refractory. A two-component diagram illustrates that the change from liquid to solid, that is, freezing, is produced over a wide temperature range in all compositions except those near pure components and eutectics. This relationship is true, even in the most complex systems.

The destructive chemical processes leading to wear of the refractory occur at fairly high temperatures – carbon disintegration takes place at about 900° F., alkali disintegration at about 1800° F., and solution by wide-range freezing slags at higher temperatures. Two approaches have been made to solve this problem: a search for refractories that will be more resistant to these actions at the temperatures concerned, and the use of cooling to keep the working-face temperature below the danger levels.

As the present aim is to hold a layer of material static on the walls, it is logical to try to do this by placing a fixed obstruction or shelf in the path of flow. Such a shelf, in a liquid like water flowing at low speeds (that is, in streamline, not turbulent flow) results in almost stagnant triangular zones fore and aft, which are only slightly disturbed by recirculation. The higher the internal friction, that is, viscosity, the more these recirculating eddies are damped out. With a granular material, which has very high internal friction, similar but completely

Blast Furnace . . .

static zones occur before and after a shelf.

The extent of the proposed water cooling is not abnormal so that no new problems are introduced. Calculated heat losses for a typical shelf system amount to no more than 0.5% of the total heat input to the furnace. Past experience has shown that coolers, if efficiently designed, can last for 20 years or more; this is not surprising in view of the superior abrasive resistance of a cold metal compared with a hot, partly liquid refractory. Renewal of cooling elements during operation is possible. In addition, repeated instances are quoted in a "Survey of Blown-Out Linings," not only of the way in which the surfaces exposed to the flow of the charge are bared, but also of burden material being trapped above and below them. This confirms that the coolers do not have a significant cooling effect on the refractory, and that they act as efficient baffles.

As a result of model work and theoretical considerations, a system of blast furnace construction has been proposed to counteract wear, scaffolds and hanging. The salient characteristics of this design are water cooled shelves and stack tuyeres. It is thought that by the joint use of these devices the life of the furnace would be increased considerably and financial saving would result.

E. C. Wright

Super-Elasticity

Digest of "A 'Super-Elastic' Single Crystal Calibration Bar", by W. A. Rachinger, *British Journal of Applied Physics*, Vol. 9, June 1958, p. 250-252.

It is generally understood that the elastic action of metal is due to a reversible change of intra-atomic dimensions with stress. When a load is applied, the atoms get a little further apart; load and extension are proportionate. If the load is too high, one part of a crystal breaks away and slips a little out of position – that is to say, deformation becomes plastic and is then irreversible. In our best spring materials, such as beryllium copper, the limiting elastic strain is about 0.5%.

Super-Elasticity . . .

For certain purposes, considerably higher values are desired, and fortunately there are certain single crystals available for this purpose. Elastic action in these is due to a reversible martensite transformation, and the limiting elastic strain may be as high as 4%. The alloy described in this document contains 3% Ni, 14.5% Al, 82.5% Cu, and was made of metals of utmost purity. A small melt was cast into a ¾-in. bar, 18 in. long; this bar was then embedded in alumina powder in a silica boat, remelted in a tube furnace, a pointed "tail" drawn from the leading end and the silica boat slowly withdrawn from the furnace at 5 in. per hr. Solidification started at the pointed tail and filled the whole section of the bar as a single crystal except for a thin layer of random crystals nucleated at surface irregularities.

On soaking this crystal 15 hr. at 1760° F., the alloy became uniformly of the beta phase, a microstructure it retained on slow furnace cooling at 1475° F., just above the boundary of the delta phase. Some delta was then generated by quenching – lowering endwise into oil at 3 ft. per min. The bar was then machined and the thin layer of disturbed metal removed by electropolishing. Most of the beta phase of the remaining single crystal was retained in metastable condition; stress causes it to transform by formation of martensite.

"This new martensite phase is generated by cooperative atomic movements in the parent matrix, and with further stressing these lenticular regions of martensite increase in size and number. The martensitic phase has the same chemical composition but a crystal structure different from that of the matrix. On stressing, the martensite forms in such orientations as to generate strains which tend to relieve the applied stress. 'Accommodation stresses' are set up from the difference in specific volume of the parent beta and the martensitic phases. In the Ni-Al-Cu alloy these accommodation stresses are borne elastically by the remaining untransformed matrix of the original single crystal and thus the martensite is both thermally and mechanically elastic." E. E. T.

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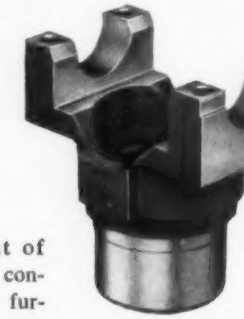

Automatic Transmission Planet Gear Carrier

Surface hardening of ArmaSteel, if desired, does not require carburizing. Instead, flame-hardening, induction-hardening or simple immersion methods may be used. A surface hardness of 50 Rockwell C to 60 Rockwell C can be readily obtained. Wear-resistant properties in the hardened area are comparable and sometimes better than carburized steel, while the remaining sections retain their original toughness.

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Because of its ability to assume the shape of practically any molded cavity, 88M not only permits great

Evaluation Test for Type 316 L Stainless

Digest of "Nitric-Hydrofluoric Acid Evaluation Test for Type 316 L Stainless Steel", by Donald Warren *A.S.T.M. Bulletin*, May 1958, p. 45-55.

THE INTERGRANULAR corrosion resistance of most austenitic stainless steels, such as Types 304, 304 L, and 316, can be adequately evaluated by means of the standard nitric acid test. However, this test is generally not used with Type 316 L because that grade of stainless is sensitive to sigma phase.

Sigma phase is formed in 316 L under essentially the same conditions that cause carbide precipitation. For example, when 316 L is given a sensitizing treatment of 1 hr. at 1250° F. and water quenched, sigma phase can be precipitated at the grain boundaries of the steel along with chromium carbides. Prior research showed that 40 out of 80 commercial heats of Type 316 L stainless steel failed the standard nitric acid test after a heat treatment of 1 hr. at 1250° F. These failures were primarily due to grain-boundary sigma phase formed during the sensitizing heat treatment. In contrast, the available evidence indicates that sigma phase does not adversely affect the intergranular corrosion resistance of 316 L stainless in corrosive media other than hot nitric acid, whereas carbide precipitation can cause severe intergranular corrosion.

Corrosion tests have been made on Types 316 and 316 L in hot acetic, citric, lactic, oxalic, phosphoric and sulphuric acid solutions. Results showed that serious intergranular attack occurred when carbides were present in the grain boundaries but not when sigma phase was similarly located and carbides were absent. These results pointed up the need for a corrosion test which could be used to evaluate Type 316 L stainless applications not involving hot nitric acid service. Such a test should be sensitive to damaging carbide precipitation and insensitive to sigma phase.

This study demonstrated that the 10% nitric, 3% hydrofluoric acid test can be standardized and successfully used for this purpose. Optimum test conditions are as follows: two 2-hr. periods in a 10% nitric, 3% hydrofluoric acid solution at 70° C. The high general corrosion rate encountered in a hot 10% nitric, 3% hydrofluoric acid solution requires the testing of two samples — one sample in the commercially annealed condition and the other in the sensitized condition (1 hr. at 1250° F., water quenched). A ratio was obtained by dividing the corrosion rate for the sensitized condition by the corrosion rate for the annealed condition. This ratio was used to evaluate the amount of intergranular attack undergone by the sensitized specimen.

The reliability of the nitric-hydrofluoric acid test was determined by evaluating 80 commercial heats of Types 316 and 316 L stainless. Each heat was also evaluated by the electrolytic oxalic acid etching test in order to microstructurally reveal any damaging carbide precipitation.

Evaluation Test . . .

Results of this evaluation are summarized below:

1. In the nitric-hydrofluoric acid test, 97% of the Type 316 L stainless heats had ratios of 1.5 or less, indicating satisfactory resistance to intergranular corrosion in the sensitized condition and the absence of damaging carbide precipitation.

2. Results of the electrolytic oxalic acid etching test correlated well with those of the nitric-hydrofluoric acid test. For the Type 316 L heats, 94% had step or dual structures (absence of damaging carbide precipitation) when sensitized and subjected to the oxalic acid etching test. All heats included in the 94% had ratios of 1.5 or less in the nitric-hydrofluoric acid test. These results show that the electrolytic oxalic acid etching test successfully predicted that 94% of the Type 316 L heats would have acceptable resistance to intergranular corrosion in the nitric-hydrofluoric acid test.

The results of the investigation indicate that the following procedure could be used for the selection of Type 316 L stainless having adequate resistance to intergranular corrosion in the as-welded condition:

1. A sample of the steel is sensitized for 1 hr. at 1250° F., water quenched, and then subjected to the electrolytic oxalic acid etching test. A step or dual structure in this test indicates that damaging carbide precipitation is not present and that no further corrosion evaluation is necessary. If the sample shows a ditch structure in the oxalic acid etching test, the steel is evaluated by the 10% nitric, 3% hydrofluoric test as outlined.

2. Two samples of the steel, one commercially annealed and the other sensitized for 1 hr. at 1250° F. and water quenched, are tested for two 2-hr. periods in a 10% nitric, 3% hydrofluoric acid solution at 70° C. If the ratio of the sensitized corrosion rate to the annealed corrosion rate is 1.5 or less, then the steel has acceptable resistance to intergranular corrosion. Type 316 L, having a nitric-hydrofluoric acid test ratio of greater than 1.5, should not be used in the as-welded condition for service involving intergranular corrosion.

A.G.G.

Flanging and Pressing of Dished Heads

Digest of "The Flanging and Pressing of the Dished Head", by Harry S. Beers. Paper presented at Philadelphia Regional Technical Meeting of American Iron and Steel Institute, Nov. 20, 1957, 23 p.

A HEAD is an inconspicuous but important component of almost every vessel used to store liquids or gases under pressure. Most heads are flanged to simplify joining them to cylindrical components and many are both flanged and dished. Some, such as the heads for tank cars, are standardized enough in size, shape and type of material to justify mass-production methods. If the quantities justify the die costs, they can be produced most economically by cold drawing or hot pressing. Frequently, however, the customer needs oversized or unusually shaped heads for specialized applications. Such components are made on flanging machines and finished on a press, or partially formed on a press and finished on a flanging machine.

There are five common shapes of heads produced regularly. They may be made from a variety of metals or clad metals depending on their intended use. By spin flanging, heads from 3/16 to 6 in. thick and from 9 in. to 19 ft. in diameter can be produced. Special machines are used for spinning the desired shapes from hot circular blanks. The normal blank temperatures are 800° F. for aluminum, 1800° F. for carbon steel and 2100° F. for stainless steel.

A flanging machine contains top and bottom clamping dies to hold the center of the head. The top die is attached to a hydraulic ram which supplies pressure to hold the blank, but the die is free to rotate. The bottom die is mounted on a driven spindle which can be rotated at about 34 to 40 rpm. The outer portion of the blank is worked between an outer (quadrant) roller and a saddle on the bottom or inside of the head. The quadrant roller is moved to control the contour during forming. The saddle may be a block or a revolving roller depending on the shape to be produced. Neither the quadrant roller nor the saddle roller is driven; they

Flanging and Pressing . . .

turn from friction against the head.

Using such a machine, a skilled operator can form a 15-ft. elliptical head from a 12-ton blank 230 in. in diameter and 2 in. thick. The outer contours and dimensions can be controlled quite closely; the interior dimensions are brought to close tolerances by machining.

Pressed heads are formed by hot or cold forming, depending on the thickness, diameter and depth of draw. Hot pressing can usually be done in flat clamping and forming dies. Cold pressing is more complex and various beaded-type dies are used depending on the contours desired. For some special orders, suitable dimensions for cold working dies have to be developed by experiment. For example, buckling is sometimes a problem in drawing large hemispherical heads. Cold worked heads are stress-relieved after forming. Some aluminum heads are heat treated before they are shipped.

F. W. Boulger

Nondestructive Testing Symbols

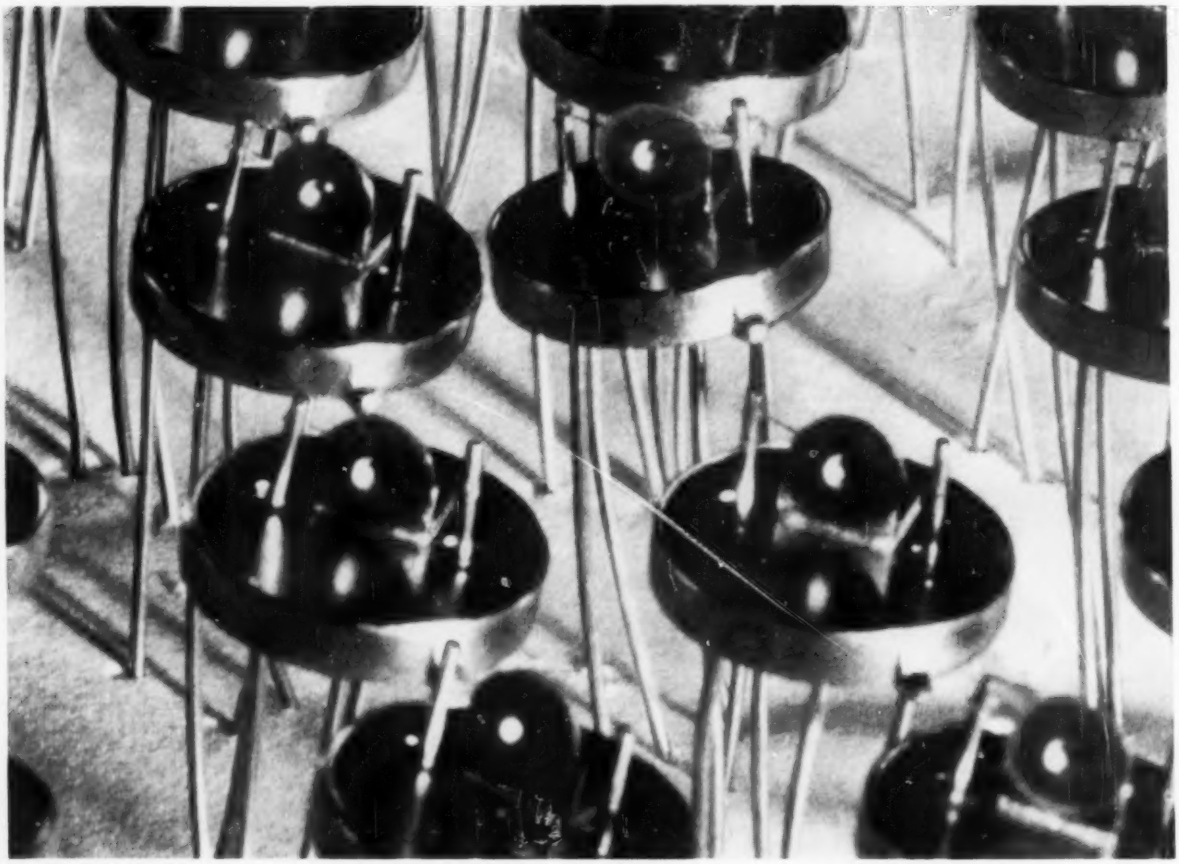
Digest of Nondestructive Testing Symbols, prepared by the Committee on Nomenclature, Definitions and Symbols, American Welding Society, 1958. 10 p. $1.00.

Some 19 representatives of industrial organizations and three government departments and research institutes have collaborated in producing this first-ever standard. This booklet is divided into three sections dealing with: basic symbols, general provisions, and methods of specifying extent of nondestructive tests.

Under the basic symbols are listed radiographic, magnetic-particle, penetrants and ultrasonic methods of testing. This section then indicates (in the now established International Organization for Standards method of using reference lines and arrows) how data regarding the required nondestructive testing methods can be incorporated.

The basic testing method, location, number, extent, specification reference, process and direction of

(*Continued on p.* 188)



IBM, Poughkeepsie, N. Y.: Critical alloying and bonding temperatures determine final operating characteristics of germanium transistors (above).

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Nondestructive Test . . .

radiation can be readily added to the welding data reference line or indicated on separate reference lines.

This early endeavor to produce some degree of standardization in this important and rapidly expanding section of the quality control of welding is highly commendable but it is noted with regret that none of the Committee as listed represent the American Society for Nondestructive Testing, American Petroleum Institute, American Gas Assoc. or American Society for Mechanical Engineers, who, it is felt, could have offered useful contributions and established that its use would be accepted by their respective bodies.

This new standard must be acceptable to all persons who are concerned with welding and with testing. It may be some time before it is fully recognized by the drawing office. The draftsman will require guidance on the data to be given, and until he is familiar with the standard he will probably require frequent reference to this booklet to ensure that he lists the correct reference.

Some confusion may arise in the use of the "test-all-around" symbol since particular industries use a similar sign to indicate "weld-all-around" or to indicate a site weld.

While much consideration must have been given to broad grouping of tests, a cause for confusion can arise in the radiographic type of test. Many specifications permit both X-ray and gamma-radiographic examination of welds and to this end it is felt that this could have been included in the standard. The reviewer would have preferred the basic methods of tests to be listed by the initial letter of the process as listed:

G.R.T.	Gamma Radiography Test
X.R.T.	X-Radiography Test
M.P.T.	Magnetic Particle Test
D.P.T.	Dye and Penetrant Test
U.S.T.	Ultrasonic Test

It is appreciated that the exponents of high-voltage and other methods of radiography might claim the incorporation of initials for their method but it is felt that these need not be included as their radiations are essentially X-rays.

The conservative approach of

(*Continued on p. 192*)

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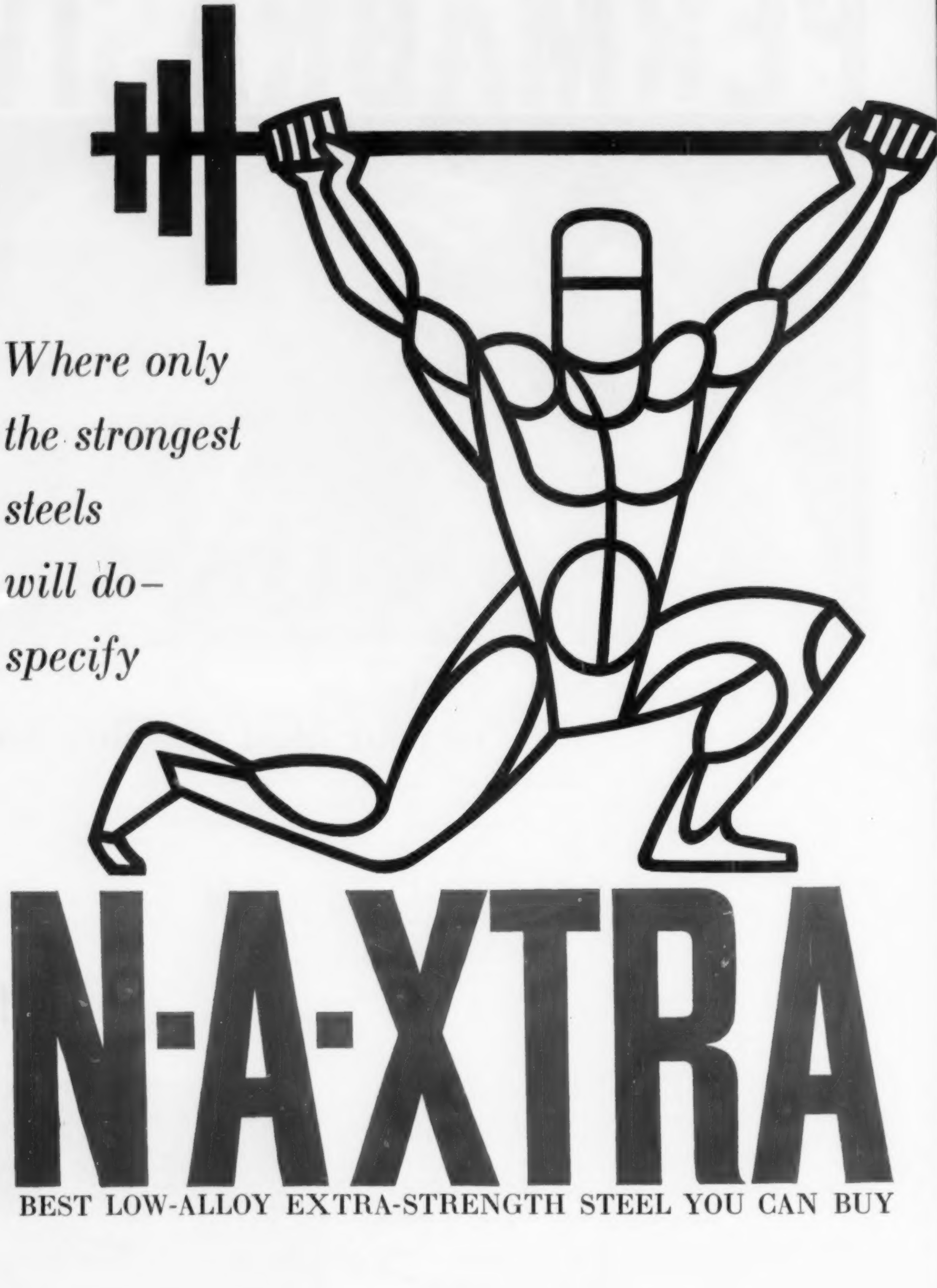
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Nondestructive Test . . .

some European countries by only producing standards and specifications based on established industrial methods and practice – then gathering all interested bodies together to produce such a standard – has much to recommend it since it will require infrequent revision of standards. On the other hand, the New World approach – that technical bodies such as A.W.S. should guide and set patterns for industry – is to be admired even if it does require the more frequent re-issue or amendment of specifications and standards.

The reviewer, while subscribing to the fact that the best of the two methods listed above should be incorporated, and having offered what he hopes is constructive criticism of this standard, does warmly commend the A.W.S. for their initiative in attempting to bring a standard into being where none existed but where one would some day be required.

C. C. Bates

Combined Creep and Fatigue Tests

Digest of "Problems of Combined Creep and Fatigue Design", by A. J. Kennedy, *Engineer*, Vol. 204, Sept. 27, 1957, p. 444-447.

In the absence of a fatigue stress, continuous creep can be broadly described as a balance between recovery and work hardening. This balance is essentially dependent on stress level and temperature. In the presence of a fatigue stress, however, the processes of work hardening and recovery are affected by the alternating nature of the stress level. During low stress periods, work hardening may be dissipated. Thus, to predict the creep properties of a material under such conditions, the kinetics of the recovery processes must be carefully considered. Since the recovery processes can occur at low stress levels under combined creep-fatigue conditions, the creep rate is accelerated by fatigue. The author gives the results of creep tests on lead at room temperature with and without superimposed fatigue stresses. The addition of 72 psi. of alternating stress reduces

Creep and Fatigue . . .

the creep life to about one third of that for the instance where the 72 psi. in. is added statically.

By applying the fatigue stress intermittently, it was possible to follow more clearly the effect of fatigue on creep deformation. It was found that, while both static and fatigue increments cause a small transient to occur, the average creep rate during this incremental period is much greater in the instance of fatigue and is equivalent to an increased rate of steady-state creep. Furthermore, when the increment of stress is removed, its effect in reducing the creep rate under the original stress is greater in the instance of the static increment. This indicates that, although the fatigue increment results in greater strains, these strains are achieved with less work hardening than that incurred by much smaller strains under completely static loading. It thus appears that the processes of creep under the two conditions are significantly different in their nature as well as in their effects. The basic phenomenon, however, is that there is more time for recovery to occur (at the lower stress) in a fatigue increment than in a static increment of stress.

An explanation of the effect of fatigue on creep may be found in the dislocation theory. As deformation occurs, under semidirectional stressing, dislocations are generated and move through the lattice building up at barriers and creating localized internal stresses. The metal thus becomes more resistant to deformation, and although on the removal of the external stress a back diffusion of dislocations may occur, some other process is required if the degree of recovery observed is to be explained. If the applied stresses are alternating, then so must the dislocations alternate. This cyclic motion of dislocations creates vacancies and collects them together into localized concentrations which accelerate recovery, at the minimum stress levels, by shifting dislocations into neighboring planes. These vacancy clusters will also set up stress levels, by shifting dislocations which will initiate microcracks and eventually lead to failure.

This work reveals clearly the

Creep and Fatigue . . .

recovery processes in creep being aided by fatigue stresses: Thus it helps develop design for service under complex stresses.

In designing for a specified deformation, the whole of the deformation effects may be approximately calculated, if the static creep properties of a material are known, by applying a time function of recovery for the dynamic portion of the stress. The time function for recovery could be determined from a few history cycles (actual complex cycles of static and alternating stresses at particular temperatures).

In order to calculate the resulting deformation from recovery, due to the low stress portion of the fatigue cycle and the work hardening occurring under the static and high stress portion of the fatigue cycle, much research will have to be done to develop methods of handling the data.

W. A. Morgan

Cold Extrusion Process

Digest of "The Industrial Application of Cold Flow Extruded Steel Parts", by H. D. Feldmann, *Wire* (English Edition), No. 27, February 1957, p. 18-29.

Cold extrusion consists of forming unheated disks, billets or preshaped blanks into components of the desired shape. Both solid and hollow bodies with various contours and diameters can be cold extruded. Employed for tin and lead tubes since 1880, gradual improvements in die materials, die designs and lubricants made the process suitable for stronger alloys. Between 1930 and 1935 it was found practical to cold extrude low-carbon steels by using special surface treatments which prevent seizing between the tool and workpiece. Phosphate coatings on the workpiece and suitable lubricants meet these requirements.

Usually more than one forming step is involved in making cold extruded parts. It is common practice to combine the extrusion operations with upsetting, drawing, perforating or pressing operations and to include annealing treatments at appropriate intervals in the process.


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Cold Extrusion . . .

Solid parts can be made with stepped shanks and with a variety of head shapes. Hollow components can be extruded with or without a bottom and with stepped external diameters. Parts with raised sections such as rifling, internal or external splines can also be extruded. The process is particularly suited to objects which are axially symmetrical.

Extrusion punches and dies must withstand service stresses ranging up to 290,000 psi. They are ordinarily made of toolsteel although sintered carbides have been used. The extrusion loads depend on die design, lubrication, amount of reduction and the strength of the workpiece. To minimize loads and wear on tooling, extrusion operations are not ordinarily performed on steels with tensile strengths exceeding 70,000 psi. in the soft condition. Steel quality is important; nonmetallic inclusions and segregates cause trouble. Plain carbon steels containing less than 0.28% carbon are suitable for most cold extrusion operations. Some parts have been extruded from low-carbon low-alloy steels. Extrusion operations ordinarily double the tensile strength of the workpiece and lower tensile elongation values about three fifths. The exact effect on mechanical properties, of course, depends on the extent of the deformation and the shape of the extrusion.

The surface finish of the tools controls the finish of cold extruded parts. Profilometer readings for typical parts range below 4 microns, intermediate between values for finely ground and for honed surfaces. The relatively high fatigue strengths reported for some extrusions are attributed to their smooth surface finishes. It is also claimed that cold extruded parts exhibit superior resistance to wear under dry and rolling friction. Both of these claims are being investigated.

As with most production methods, costs increase rapidly as tolerances are narrowed. The variation in length among cold extruded parts depends largely on the variation in billet weights and is normally about 0.08 to 0.16 in. For solid parts 2 to 3 in. in diameter, up to 28 in. long, the usual tolerances are ±0.009 in. on diameter and 0.034 in. on straight-

Cold Extrusion . . .

ness. For hollow components, the eccentricity is usually between 0.5 and 1.2% of the nominal external diameter. The ovality of the diameters ranges between 0.2 and 0.6% of the diameters. Closer tolerances can be maintained but the use of extrusion methods for parts requiring extremely close tolerances is usually questionable.

The application of cold extrusion methods ordinarily results in savings in weights of raw material and in avoiding some machining operations. Components which ordinarily require considerable machining and rechucking are often suitable for production by extrusion. On the other hand, cost comparisons usually favor automatic lathes for parts which can be made with one chucking operation and little loss in metal. This is especially true if the extrusions require some finish machining.

The presses and tools required for cold extrusion processes are comparatively expensive. The process, therefore, is best suited to mass production. The minimum economic lot size decreases as the weight of the part increases. A rough guide to economic lot sizes is: 5000 for parts weighing 0.1 to 1 lb., 3000 for parts weighing 1 to 20 lb., 1500 for heavier parts. These figures would vary considerably with the complexity of the workpieces.

F. W. Boulger

Electroslag Welding of Titanium

Digest of "Certain Questions Concerning the Electroslag Welding of Titanium", by S. M. Gurevitch and V. P. Didkovskij, Automaticheskava Svarka, No. 3, 1957, p. 85-91.

THE ELECTROSLAG welding process is similar to submerged-arc welding in that the electrode dips into a puddle of molten flux. In the former process, however, there is no arc, heat being generated by passage of electric current through a layer of conductive flux lying on the metal. The process, developed ten years ago by the Ukrainian Electric Welding Institute for welding steel, is now used by the Institute for welding heavy sections of titanium since

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Electroslag Welding . . .

inert-gas-shielded arc welding, submerged-arc welding, and pressure welding are less effective. In electroslag welding, progression of the weld puddle is vertically upwards, and copper molds are used to contain the molten flux and metal within the joint.

The flux used for electroslag welding of titanium contains no oxygen. At first the same flux (AN-Ti) used for submerged-arc welding was tried. It started easily and could be used over a wide range of currents, 700 to 2300 amp. a-c. It generated a great deal of gas, which forced the development of a flux (AN-Ti 2) having higher melting and boiling temperatures. Even with this flux the air dissolved in it and contaminated the metal. Deepening the puddle to 3¼ in. did not prevent contamination of the metal.

Several gases were tried as a gas shield above the slag: argon (pure and commercial), CO_2, natural gas, and chlorine. Pure argon provided the best shield:

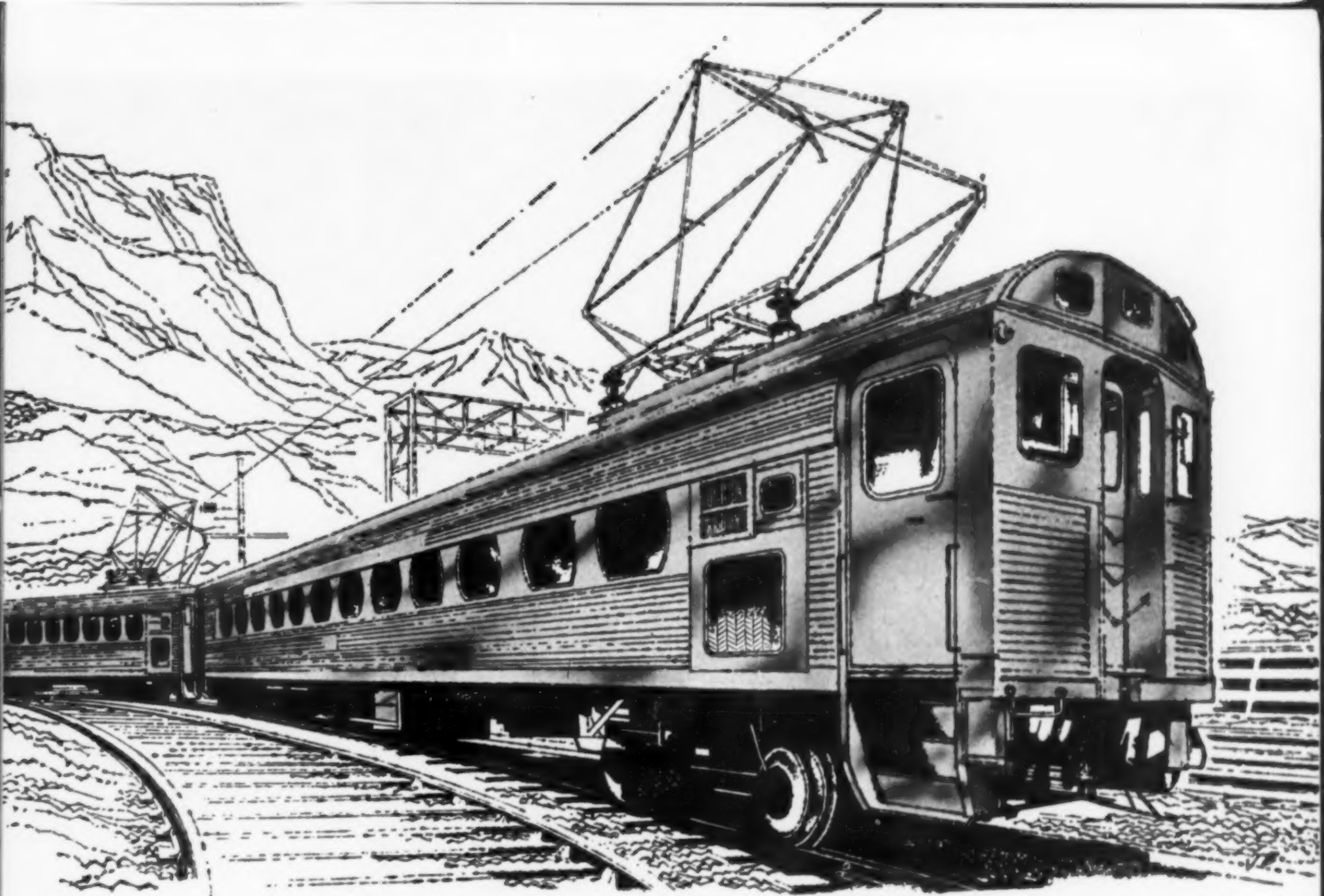
	Without Gas Shield	Argon Shielded
N_2	0.369%	0.06%
O_2	1.22	0.11
H_2	0.07	0.01
Rockwell hardness	C-61	C-18

An argon flow rate of 6.3 to 8.4 cu.ft. per hr. was sufficient for joints 4 in. thick in commercial titanium.

To weld joints in 4-in. titanium, the electrode was a strip 4 in. wide and 5/16 in. thick. A constant potential, single-phase welding transformer was used. The strip was fed at the rate of 1.6 to 2.6 in. per min. The depth of the slag puddle was 1 to 1⅛ in.

The microstructure of the welds was found to consist of coarse-grained acicular alpha prime, which may have low ductility. For this reason welds were made at energy inputs from 0.64 to 0.89 kw-hr. per in. of weld, corresponding to 1600 amp. at 20 v. and 2200 amp. at 25 v., respectively. The weld made at the lower energy had smaller grains and finer needles of alpha prime than the weld made at the higher energy.

D. L. CHURCHILL



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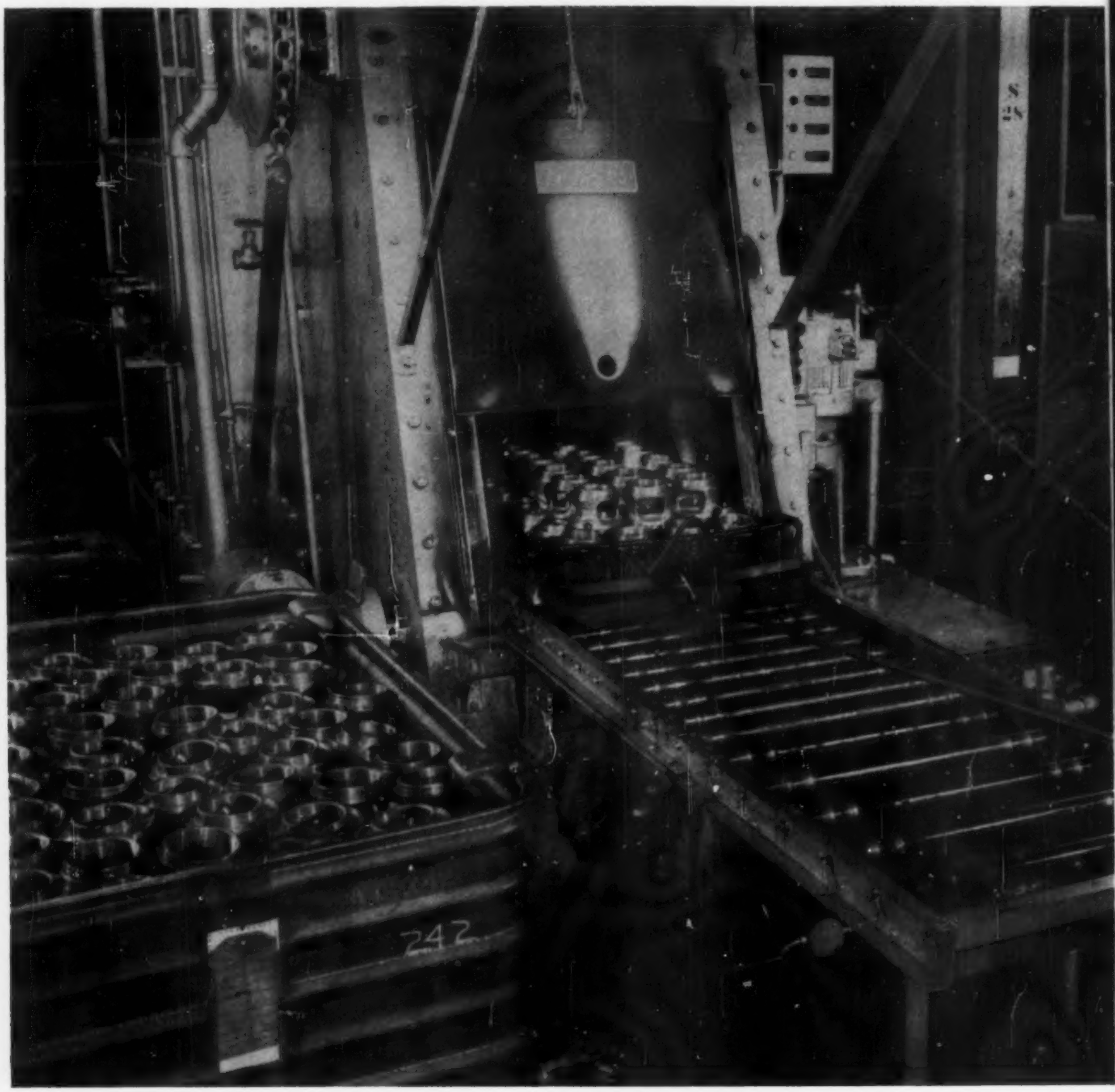

Ridge Tool Company reports:

"We hold 3 3/16" tap holes in malleable iron to

That's the word from Christopher Thome, Heat Treat Foreman at Ridge Tool Company, Elyria, Ohio—world's largest pipe tool manufacturer. Their RIDGID pipe wrenches—and other related tools—are bywords wherever pipe is handled.

"Since we changed to Gulf Super-Quench in our heat treating operations," says Mr. Thome, "we've had considerably less distortion in carbonitrided parts having variable sections and large bore sizes.

"Speaking of large bore sizes, we have tap holes of 3 3/16" in workholders of our RIDGID true-centering, jam-proof threaders. Because these large-bored pieces are of malleable iron, they are doubly subject to distortion in quenching.

"But with Gulf Super-Quench in the internal bath of our Lindberg furnace, we can hold to within .003" on these tap holes. Quite a close tolerance for a bore size of 3 3/16" in a metal like malleable iron.

"We also use Gulf Super-Quench in our Cincinnati Flamatic. Here it gives us maximum selective hardening penetration in such parts as hook jaws for pipe wrenches and large bored gears for pipe threader power drives. Distortion is a negligible factor here, because of the cooling range efficiency of Super-Quench."

Emerging from quench bath in this Cincinnati Flamatic, at Ridge Tool Company, are hook jaws for their 36" RIDGID pipe wrenches. Jaw teeth are assured of maximum selective hardening in Gulf Super-Quench.

Christopher Thome, left, Heat Treat Foreman, Ridge Tool Company, shows Gulf Sales Engineer, T. F. Irving, one of the hook jaws hardened to desired specifications in Gulf Super-Quench.

◀ Out of this Lindberg furnace, at Ridge Tool Company, comes a basket of malleable iron workholders for their RIDGID pipe threaders. Pieces are carbonitrided to .005" case depth. Soak: 30 mins. at 1400 F. Quench: 25 mins. in Gulf Super-Quench at 180-200 F. Superficial hardness reading after cooling: 15N90. Tap holes, of 3⅜" diameter, held to within .003".

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Selecting Hardenable Steels

Digest of "A Critical Commentary on Steel Selection: Ruling Section or Hardenability", by H. E. Arblaster, *Journal*, Australian Institute of Metals, Vol. 2, December 1957, p. 194-213.

The author has presented much thought-provoking material in comparing two methods of selecting hardenable steels: consideration of hardenability as used in the United States or of ruling section as applied in Britian.

With respect to chemical composition, the American approach is to apply a check analysis tolerance over and above the nominal range of specification for each element. This permits individual analysis on any product from a given heat to vary from the specified range by the amount given for each element in the tolerance table. It is questionable, however, whether this is close enough control. The British approach chemical composition by requiring that the cast analyses comply to specified ranges. Any subsequent checks on products from a given heat must then adhere to the cast chemistry within a stated tolerance for each element. The principle here is that a purchased bar or billet should be reasonably close to the stated chemistry of the heat from which these products were rolled.

The Americans select steel on the basis of hardenability, applying the results of the Jominy end quench test. This has established a new classification of steel, the "H" band steels, which describe maximum and minimum hardnesses at different locations on the Jominy bar. These results can be readily transposed to bars of varying section and at any given location in that particular bar section. Consideration must also be given to the structure at a particular location in a bar. There are, however, differing opinions of the necessary structure to withstand a given service. This desired structure might vary from 50 to 90% martensite. The location in the bar section where the required structure must exist will depend upon the severity of service conditions.

In Britain, steel selection is based on "ruling section", which is that

Hardenable Steels . . .

portion of a bar that is most important from the point of view of heat treated mechanical properties. This is expressed in terms of an equivalent round bar. The steel must meet a specified minimum tensile and Izod test, graduated in relation to the ruling section. Thus no definition of structure or hardenability is given. The criterion is that specified mechanical properties at a given location in a bar will be met and guaranteed.

The end quench hardenability test is only concerned with hardness, and thus gives no accurate indication of other mechanical properties or of structure. This is primarily due to the fact that steel is heterogeneous. If the end quench test bar is taken at different locations in the product from a given ingot, variations will be found in the results. These differences can only be based on the occurrence of microsegregation, which can exist down to quite small bar sizes.

While much concern has been given to the percentage of martensite at a specified location in a bar, it is perhaps of greater importance to consider the nature of the remaining 50% of the structure. It is this latter product that can have a more specific influence on the ultimate mechanical properties developed. This was indicated by H. W. Gillett when he wrote, "The user must by some means or other supplement the hardenability data by specific tests of his own to ensure adequacy for his use".

In relating hardenability data to mechanical properties, a close correlation occurs at a level of approximately 120,000 psi. Exceptions appear, however, and increase proportionately at higher strengths. But it would be more practical to pay greater attention to the hardened and tempered Jominy curves. This would reduce wide variations in results from a given composition, and offer more realistic comparisons to the condition in which the steel will be ultimately used in service.

It is also important to consider the individual effects of different alloying elements. Obviously, the properties of slack quenched products will vary appreciably in a 50% martensite structure in accordance

Hardenable Steels . . .

with the type of alloy present. Further, variations in Izod properties at a constant hardness will exist in accordance with the chemistry. Finally, the comparative properties of various bainite structures will show that they have acceptable properties that are even superior to those of tempered martensite in resisting creep. While it is agreed that tempered martensite offers optimum properties, it may not always be economical to obtain this condition through overalloying. Acceptance of alternative structures can only be truly determined by actual physical tests.

B. M. Hamilton

Electroless Nickel Plating of Silicon

Digest of "Electroless Nickel Plating for Making Ohmic Contacts to Silicon", by M. V. Sullivan and J. H. Eigler, *Journal*, Electrochemical Society, Vol. 104, April 1957, p. 226-230.

The use of silicon in semiconductor devices requires at least two electrical connections to the silicon. Simple, direct soft-solder connections to silicon have not been possible to date. Contacts have been made by alloying metals soluble in silicon under high-temperature conditions. However, the depth of penetration of the surface contact metal is difficult to control. Except for the case of lead, the resulting alloys are brittle, mechanically unsound, and the high temperatures involved generally result in a loss of the minority charge carrier lifetime of the silicon. An electroless nickel plate between the silicon and soft-solder is outstanding from both a mechanical and electrical standpoint.

Electroless nickel is deposited by the catalytic reduction of nickel from solutions as described in the literature by A. Brenner and others. Even distribution of nickel is inherent in the process, and no special cleaning of silicon appears necessary to insure good adhesion. The author measured an initial deposition rate of about 0.02 mm. Ni per hr., but after an hour the rate dropped to approximately 0.005 mm. per hr. under the operating

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Nickel Plating . . .

conditions. The bath chosen by the author for his work was as follows:

Nickel chloride	30 g. per l.
Sodium hypophosphite	10
Ammonium citrate	65
Ammonium chloride	50

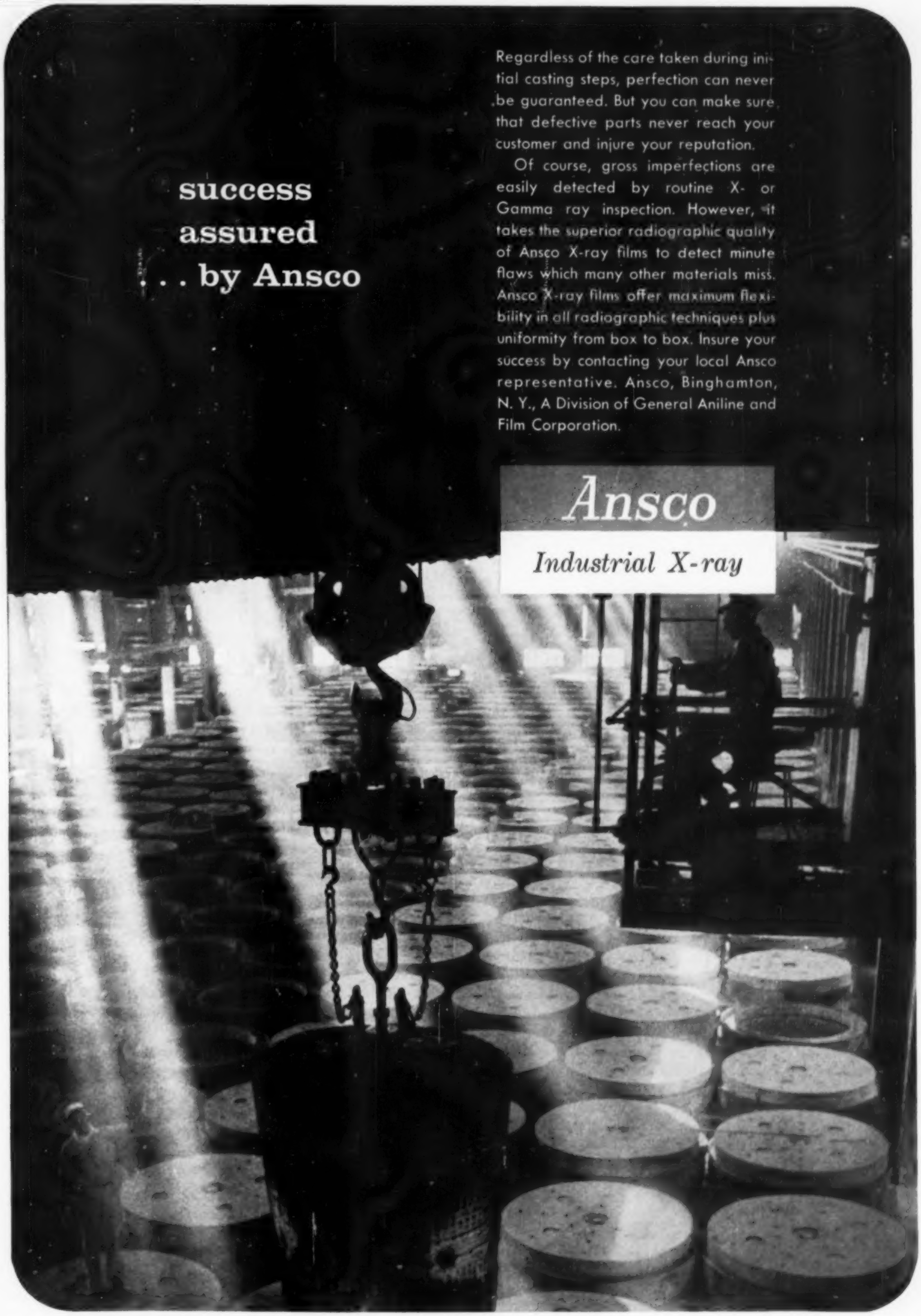
The solution was filtered and ammonium hydroxide was added until the solution turned from green to blue (pH 8 to 10). The operating temperature should be as close to 97° C. (207° F.) as practical; the pH is maintained by additions of ammonium hydroxide.

The author's silicon specimens were prepared in two ways: In the first, "polished" specimens were mechanically polished with various grades of abrasives ending with 0.1 micron, Al_2O_3. They were given a chemical etch (44% HNO_3; 18% HF; 38% H_2O). Immediately prior to plating, the specimens were given a 10 sec. dip in HF (48%) and thoroughly rinsed in water. The second cleaning technique involved "lapped" specimens, lapped with 600-mesh carborundum and scrubbed with sodium hexametaphosphate and water. Immediately prior to plating, the specimens were dipped for 3 to 5 min. in boiling NaOH (5%) and rinsed thoroughly in water. Room-temperature HF (48%) substituted for the hot NaOH gave no apparent change in results.

The adhesion of electroless nickel to silicon was ascertained by measuring the force required to pull a soldered wire from the surface. On lapped surfaces the break was always in the silicon. On polished surfaces the separation was predominatly at the silicon-nickel interface although small sections of silicon were pulled out. Optimum adherence was observed for approximate plate thicknesses of 0.002 mm. for lapped surfaces and 0.001 mm. on polished surfaces.

Contact resistance on n-type silicon decreases as a result of high-temperature annealing but a maximum in resistance is obtained after treatment at intermediate temperatures where the hardness of the electroless nickel approaches a maximum of 300 to 400° C. (570 to 750° F.).

Introduction of a highly doped silicon between the nickel and main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Nickel Plating . . .

body of silicon lowers the resistance appreciably. This layer is obtained by diffusion of phosphorus from the gaseous phase into the silicon. This is a common technique in diode fabrication. On p-type silicon high-temperature annealing causes the contact resistance to become very great and rectification may be observed. Contact resistance may be considerably reduced by the introduction of a highly doped layer on the surfaces of the silicon. No peak occurs in the curve of contact resistance as a function of annealing temperature of either type silicon having the highly doped intermediate layer. W. H. METZGER

Bright Anodizing Aluminum

Digest of "The Anodizing and Brightening of Aluminum and Its Alloys", by A. W. Brace, *Metallurgia*, Vol. 55, April 1957, p. 173-185.

ALUMINUM now ranks by volume as the second most widely used metal. In comparing bright anodized aluminum with bright chromium-plated aluminum, as a finish on automobiles and appliances, several things must be considered. The relatively high cost of nickel-chromium plating on aluminum tends to retard the development of such finishes for arduous exterior service. This is because of the more elaborate preplating treatments and thicker coatings required for reasonable performance. The failure of a plated deposit on aluminum is particularly objectionable. The growth of blisters and peeled coatings is accelerated by the high potential difference between the metals at their interface.

An alternative finish for aluminum has been practiced in Great Britain for about twenty years. This finish is bright anodizing. With high-purity metal, it is possible by various electrolytic and chemical treatments to increase the total reflectivity of a suitably prepared surface, and to retain this by anodizing in a suitably chosen sulphuric acid electrolyte. The brightness obtained on

Bright Anodizing . . .

anodized aluminum is largely dependent on the composition and metallurgical condition of the material. The reflectivity of pure aluminum after anodizing is a direct function of its purity, and 99.99% represents the highest standard obtainable commercially at present.

The available brightening processes for aluminum fall into two classes: electrolytic and chemical. Electrobrightening processes increase the surface reflectivity of aluminum objects which are treated anodically under conditions suitable for brightening. Electropolishing solutions give a definite smoothing action in addition to brightening. Chemical brightening processes are acid mixtures operated around 212° F. and require only simple immersion of the aluminum. Those compositions based on phosphoric acid work quite well on less pure grades of aluminum and can give a fair degree of smoothing. Compositions based on hydrofluoric, chromic and nitric acids brighten but have little smoothing action. One ammonium bifluoride-nitric acid mixture has a pronounced smoothing action but only brightens material of around 99.99% purity and some alloys. In general, the object must be highly finished by mechanical polishing before brightening. However, a lightly etched surface or one finished with a fine-grit abrasive wheel normally is the best for electropolishing.

Composition and structure have a profound effect upon the final brightness of an article after anodizing. Total reflectivity decreases almost linearly with impurity content, and the decrease in specular reflectivity is even greater. The decrease in specular reflectivity is also greater as the anodic film thickness is increased. In order to produce a bright finish, comparable to that of decorative chromium plate, the material must be homogeneous. This restricts the choice to 99.99% aluminum and solid solution alloys based on this purity. For less exacting applications, metal of 99.5 to 99.7% purity is satisfactory.

To insure a bright finish, it is necessary to select an alloying metal

Bright Anodizing . . .

whose oxide has a refractive index close to that of aluminum oxide and which is colorless. Defects in bright anodized surfaces, such as reticulation, have no direct relation to final grain size, but there exists a direct relation to the as-cast grain size. The addition of grain refining elements reduce the brightness after anodizing, so casting conditions and physical cleanliness of the metal must be carefully controlled. Pre-extrusion of the aluminum ingots used gives a first-class product. A heavy reduction of slab thickness is essential. These and other problems make it difficult to produce a high-quality product on a mass-production basis.

W. H. METZGER

Multipoint Recorder

Digest of "A 96-Point Aircraft Temperature Recorder", National Bureau of Standards *Technical News Bulletin*, August 1958, p. 165-166.

A. B. CASTLE, SR., of the mechanical instruments section of the National Bureau of Standards, has built a prototype instrument for recording at 6-sec. intervals as many as 96 temperature readings. While it is primarily designed to study temperature distribution in various aircraft members, it doubtless will have other applications.

All components are contained in the 10 × 10 × 20-in. aluminum box shown in the illustration. Thermocouple terminals are on the outside. By selector switch, these are connected in groups of eight each half-second to four double electrical meters, each with two dials and pointers. These are shown at the four corners of the central partition, and they are photographed synchronously as a single frame of a 16-mm. movie film. The camera itself is installed behind the partition and photographs the dials by way of a mirror on the inside of the facing end wall. A standard reel of film will record operations for 15 min. Several modifications were made in the camera, such as installing an electrical drive to replace manual winding, gadgets for remote control, for synchronizing shutter and selector switches, and for using any portion of the entire 96 thermocouples, connecting them and photographing them at correspondingly shorter intervals.

E. E. T.

Operator Is Placing Reel of Film in Movie Camera, Housed in Box Containing All Equipment For Photographing Readings From 96 Thermocouples At 6-Sec. Intervals

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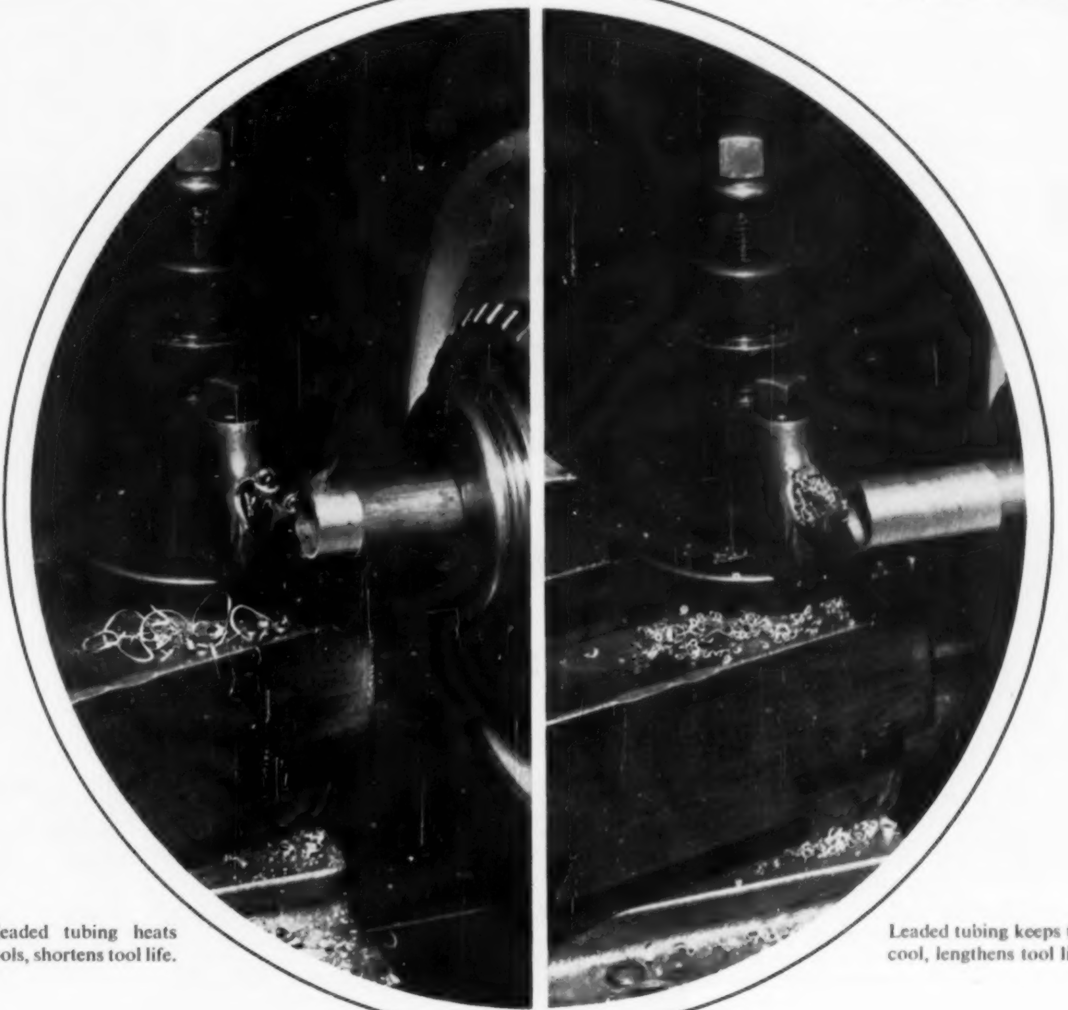


Nonleaded tubing heats up tools, shortens tool life.

Leaded tubing keeps tools cool, lengthens tool life.

Now Superior Carbon Steel Tubing with Built-in Lubrication

New leaded 1020 tubing permits faster speeds and heavier feeds, often reduces the number of finishing operations

Where machinability is of major importance, specify Superior Seamless Leaded 1020 Tubing. Its built-in lubrication permits faster speeds in turning, drilling, tapping, milling, grinding and other machining operations, provides an 18% increase in feeds, and often reduces the number of finishing operations required to produce a smooth, lustrous surface. Build-up of metal at the cutting edge of the tool is minimized. Chip formation is improved. Tools operate at lower temperatures, last longer, and require fewer dressings. Lower tool cost is an accompanying benefit. Another is reduced downtime for replacement of dull and wornout tools. There is virtually no difference in physical and mechanical properties between leaded and nonleaded carbon steel tubing. So the grades are interchangeable.

Superior Seamless Leaded 1020 Tubing is available in a range of ODs from .012 through 1⅛ in. For particulars, send for Data Memorandum No. 24. And remember that other small-diameter tubing is available in more than 120 analyses, meeting a very broad range of applications. Superior Tube Company, 2008 Germantown Ave., Norristown, Pa.

Superior Tube

The big name in small tubing

NORRISTOWN, PA.

All analyses .010 in. to ⅝ in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST

no.8
OF A SERIES

THE SOUND . . . AND THE JURY

The quiet, solid feeling inside the 1959 Oldsmobile results from patient testing by a highly specialized "jury"—experts in the field of sound analysis.

Unlike most other phases of automotive engineering, there are no instruments which measure the "annoyance" factor of sounds inside an automobile. Subjective, personal evaluation known as the "jury system" is the most important means of determining how quiet it is inside an Oldsmobile.

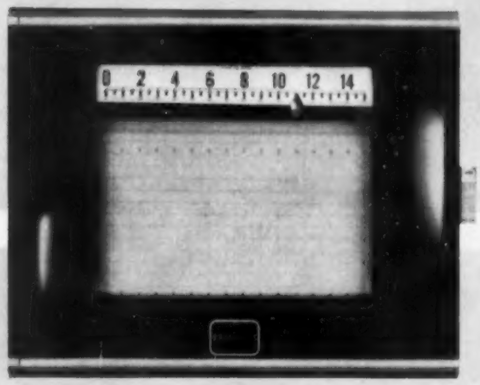
With the "jury system", several experienced engineers assemble in an acoustically treated room and listen to binaural tape recordings made inside a test car. Careful editing of the tape recording allows rapid side-by-side comparison between two different test conditions and eliminates reliance on memory since considerable time may elapse between actual tests. By pushing a button, each engineer casts a secret "vote" and then the tabulation of the results determines which test condition is superior.

For the greatest possible accuracy, considerable care is taken making the recordings. Special microphones are placed at points corresponding to the passengers' ears. The recording equipment is in a specially equipped vehicle which follows the test car over a "ride road" that is carefully constructed to excite the vibrations and sounds that occur under normal driving conditions.

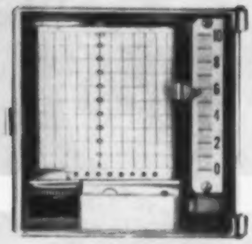
Quality, like quietness, is not accidental. It is the deliberate effort by Oldsmobile engineers to *design* quality into every automobile they produce. You'll like the 1959 Oldsmobile—with its solid Body by Fisher—it's the quietest car built! Experience this quality for yourself by visiting your local Authorized Oldsmobile Quality Dealer as soon as possible.

OLDSMOBILE DIVISION
GENERAL MOTORS CORPORATION

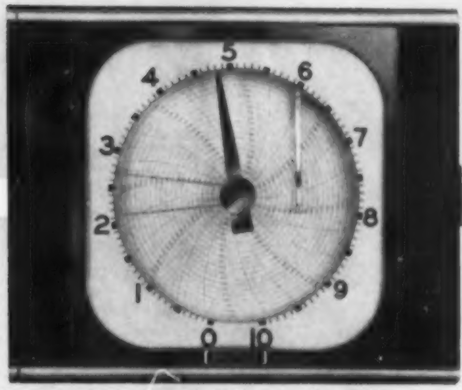
OLDSMOBILE **Where Quality is Standard Equipment!**



Dynamaster Electronic Potentiometer Pyrometer—Strip-chart model records on chart 11" wide, 120' long.



Miniature Electronic Dynamaster Pyrometer—Records on 3" strip-chart. Indicator model features easy-to-read 9" scale length.



Dynamaster Electronic Potentiometer Pyrometer—Round-chart model records on 12" chart, indicates on extra large scale.

Bristol Millivoltmeter Pyrometers—Free Vane* pyrometer controllers (shown) or indicating types. Many control modes available.

MODERN PYROMETERS...key to profitable use of HEAT

Bristol recording and automatic controlling pyrometers for temperatures up to 5000°F can help you increase product uniformity, cut fuel and maintenance costs

Bristol makes a wide range of pyrometers for every requirement: Electronic potentiometers, millivoltmeter and radiation types . . . for furnaces, ovens . . . every type of heating equipment, every kind of fuel. The reliability and accuracy of these precision instruments have been proved in thousands of installations.

Take just one advanced Bristol instrument, for example, the Electronic Dynamaster* Potentiometer Pyrometer:

CONTINUOUS STANDARDIZATION PLUS ACCURACY OF STANDARD CELL

Continuous standardization in Dynamaster Electronic Pyrometers requires no dry-cells, **but still retains the precision standard cell for highest stability and accuracy of voltage reference.** Results: No interruption to operation, no batteries to change. And here are just a few of the Dynamaster types available:

A model for every requirement: Dynamaster Pyrometers are available as single-pen, two-pen, and multiple-record (up to 24 points) *strip-chart* instruments and as *round-chart* instruments.

Electric and pneumatic controllers: Both strip- and round-chart instruments are made in a very wide variety of controllers that meet every furnace and oven control requirement, including the following in a great many forms:

Electric Control—on-off, proportional input, 3-position, proportioning, proportional with automatic reset, and time-program.

Pneumatic Control—on-off, proportional, and proportional with reset.

Miniature Dynamaster Pyrometer: Full plug-in flexibility . . . takes only 5" x 5⅛" of panel space, but has same basic accuracy, same time-tested operating principle as full-size Dynamaster pyrometers described above. Ideal for graphic panels and centralized recording or indicating of large numbers of variables. Either electrical or pneumatic control types available.

Write for complete data on Bristol Pyrometers—and remember Bristol offers a complete line of thermocouples and pyrometer accessories. The Bristol Company, 106 Bristol Road, Waterbury 20, Conn. *T.M. Reg. U.S. Pat. Off. 9.9

BRISTOL... for improved production through measurement and control

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

The Image of CF&I offers . . . for every industry . . .

Wissco Woven Wire Processing Belts

The giant steelman reflects generations of steel-making experience that results in durable, more efficient steel products for industry. For processing and conveying purposes, CF&I-Wissco Woven Wire Metal Belts offer these advantages for friction or chain edge drives:

Open Mesh—Allows free drainage—permits free air circulation for fast, uniform heating and cooling.

Strength of Metal—Fabricated to specifications in plain, tinned, galvanized, stainless or special alloy steel, Wissco Belts provide long, trouble-free service.

Corrosion Resistance—You can select a steel belt—high carbon, galvanized or stainless—which minimizes replacement costs and reduces maintenance.

These advantages mean long operating life and increased production for you, and make Wissco Belts a "must" where temperature extremes and every day wear factors are severe. You'll find that Wissco Belts are ideal for baking, cooling, drying, degreasing, spraying and washing.

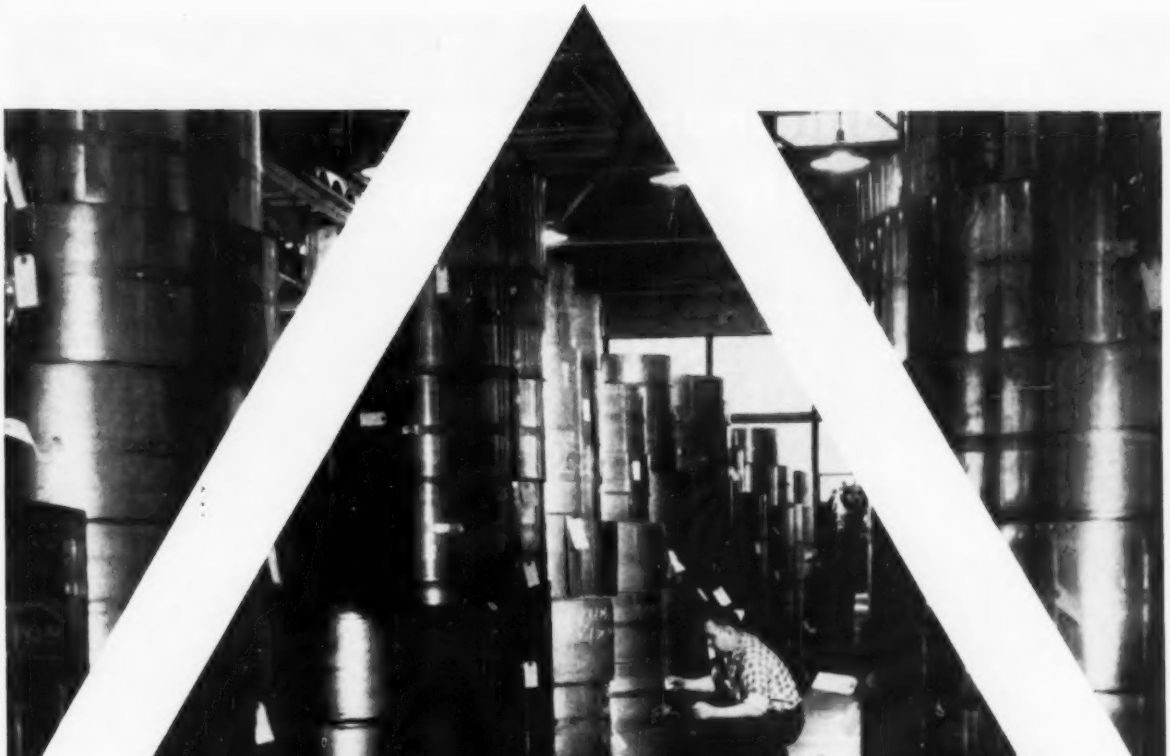
If your operation uses temperatures 800° to 2100°F and higher, specify Wissco Alloy Steel Belts. They are furnace-tested to assure dependable, smooth performance, and are excellent for annealing, hardening, enameling, sintering and similar operations.

In addition, special alloy Wissco Lehr Belts with flat supporting surfaces are available for glass annealing and decorating.

Call our experienced representative today for complete information on the Wissco Belt that will best fit your manufacturing process. And remember, Wissco Belts are usually shipped on reels for fast, simplified installation.

WISSCO BELTS
THE COLORADO FUEL AND IRON CORPORATION

In the West: **THE COLORADO FUEL AND IRON CORPORATION**—Denver and Oakland
In the East: **WICKWIRE SPENCER STEEL DIVISION**—Atlanta · Boston · Buffalo
Chicago · Detroit · New Orleans · New York · Philadelphia
CF&I OFFICE IN CANADA: Montreal 6782



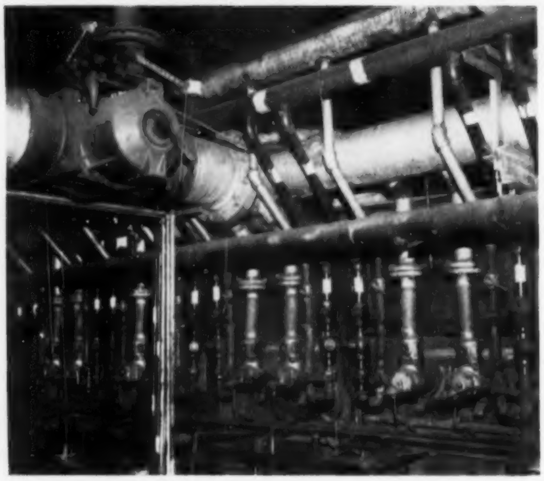
Right Down Your Spring-Steel Alley

The spring steel you need may be sitting in our mill—ready to ship from stock or to roll, slit, heat-treat and finish to your specifications—but fast. Strip steels in widths up to $6\frac{1}{2}''$ tempered and $13''$ annealed or hard-rolled. You specify temper, finish, color, edge, forming properties, tolerance, etc. Find out about these "steels of a lifetime." Write for our 4-page folder highlighting products made from Wallace Barnes Spring Steel. Try us on your next requirement.

Wallace Barnes Steel Division
Bristol, Connecticut

Associated Spring Corporation

5909



Atlas Steels Limited's Utilities Engineer says: "Maintenance is confined to the water-cooled rolls and the refractory. This furnace has proven that special and complex heating equipment is not required to obtain very high thermal releases in a small space."

This high thermal head furnace heats 2¼"x 20" stainless steel slabs for one-step reduction to ⅛" in a planetary rolling mill. Slabs pass through the 108 ft., 7 zone furnace in only 14 minutes including soak time.

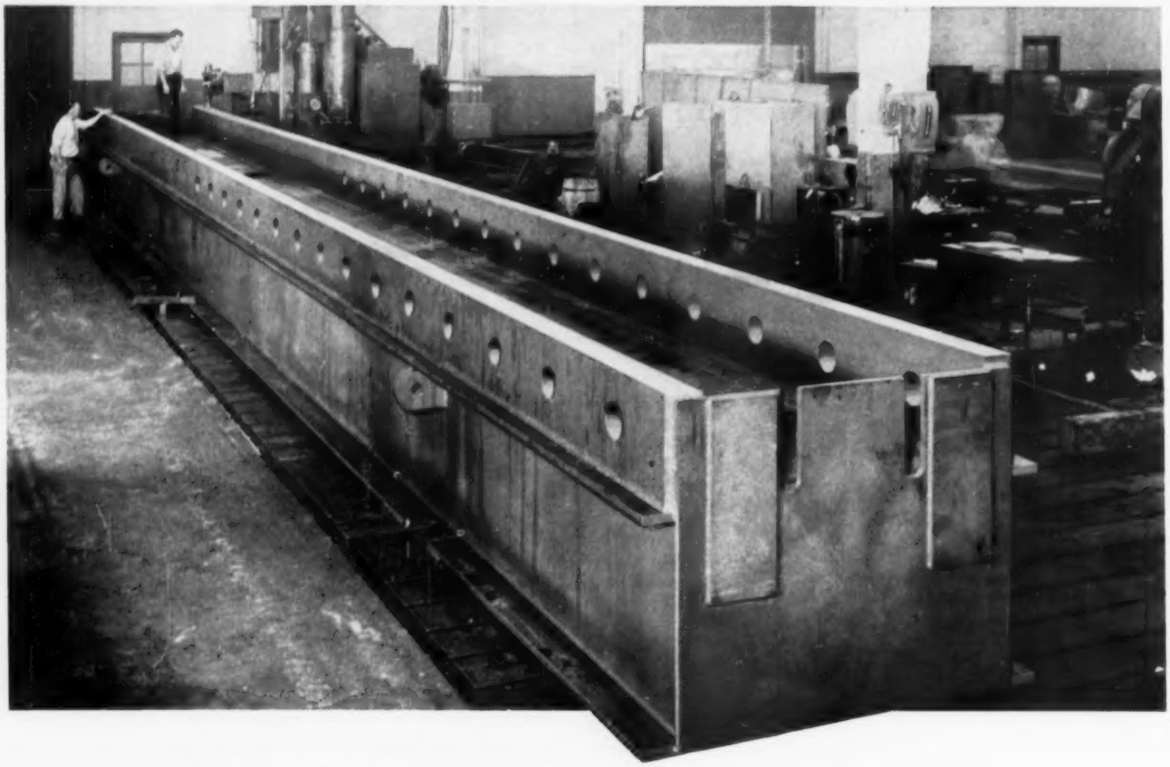
The elliptical combustion chamber is fired tangentially with 2 rows of North American Series 221 Dual-Fuel Burners. N. A. Adjustable Port Valves and #600 Air Motors Control the input.

You too can save money—specify North American burners, blowers, and controls—they're built for high production without high maintenance.

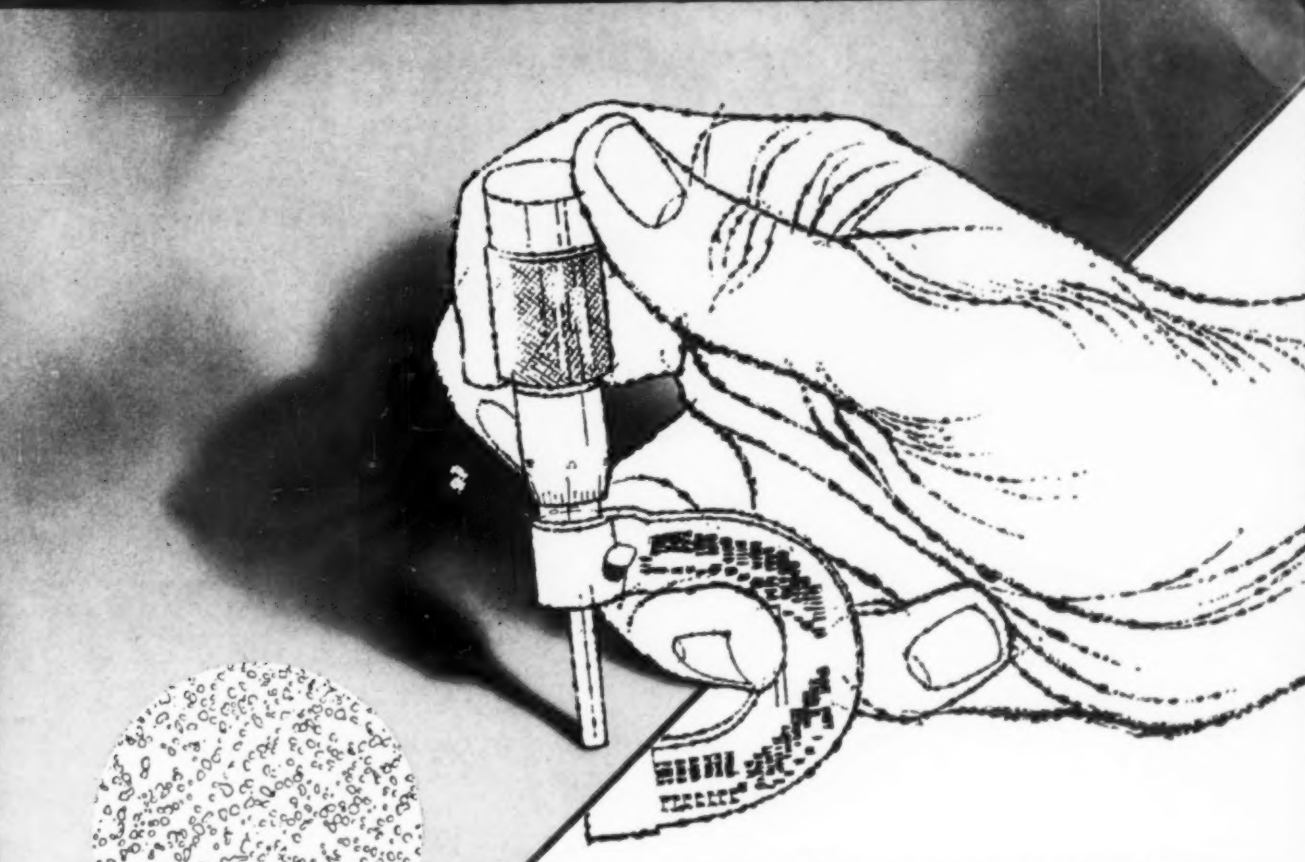
For engineering information,
call your nearby North American Combustion Engineer or write to ▼

NORTH AMERICAN for COMBUSTION and Hydraulic Controls

The North American Mfg. Co.
Cleveland 5, Ohio




ROCKET ENGINES
NEW tungsten linings
for rocket nozzles . . .



J&L COLD ROLLED SPRING STEELS...
PRECISION INSIDE AND OUTSIDE

INSIDE—Microstructure control through processing techniques developed by J&L offers important advantages. For example, improved stamping, forming and drawing qualities; uniform response to heat treatment; reduction of heat treating distortion. This product is available in various internal structures and is also available in all hardness ranges—dead soft, intermediate and spring tempers.

OUTSIDE—Superior gauge accuracy of J&L precision spring steels made possible by specially developed rolling mill equipment and techniques, saves production dollars. For example, elimination of grinding for gauge accuracy; lower inspection costs; longer tool life; smoother surface finishes.

Investigate the cost-saving possibilities offered by J&L cold rolled spring steels. Contact J&L Stainless and Strip Division, Youngstown 1, Ohio.

J&L

STRIP

LOW CARBON • HIGH CARBON • ALLOY • STAINLESS
TEMPERED SPRING STEEL • ZINC AND COPPER COATED

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The 14th METALLOGRAPHIC EXHIBIT

Chicago, November 1 to 6, 1959

All metallographers—
everywhere—
are cordially invited to
display their best work.

RULES FOR ENTRANTS

Exhibitors do not need to be members of the American Society for Metals.

Work which has appeared in previous metallographic exhibits held by the American Society for Metals is unacceptable.

Photographic prints should be mounted on stiff cardboard, extending no more than 3 in. beyond edge of print in any direction; maximum dimensions 14 by 18 in. (35 by 45 cm.). Heavy, solid frames are unacceptable.

Entries should carry a label on the *face of the mount* giving:

Classification of entry.

Material, etchant, magnification.

Any special information as desired.

The name, company affiliation and postal address of the exhibitor should be placed on the *back of the mount* together with a request for return of the exhibit if so desired.

Entrants living outside the United States should send their micros by first-class letter mail endorsed "Photo for Exhibition—May Be Opened for Customs Inspection".

Exhibits must be delivered before Oct. 15, 1959, either by prepaid express, registered parcel post or first-class letter mail, addressed:

Metallographic Exhibit
American Society for Metals
53 W. Jackson Blvd.
Chicago 4, Ill., U.S.A.

CLASSIFICATION OF MICROS

Class 1. Cast irons and steels.

Class 2. Carbon and alloy steels (wrought).

Class 3. Stainless steels and heat resisting alloys.

Class 4. Aluminum, magnesium, beryllium, titanium and their alloys.

Class 5. Copper, nickel, zinc, lead and their alloys.

Class 6. Uranium, plutonium, thorium, zirconium and reactor fuel and control elements.

Class 7. Metals and alloys not otherwise classified.

Class 8. Series showing transitions or changes during processing.

Class 9. Welds and other joining methods.

Class 10. Surface coatings and surface phenomena.

Class 11. Slags, inclusions, refractories, cermets and aggregates.

Class 12. Electron micrographs.

Class 13. Results by unconventional techniques.

Class 14. Color prints in any of the above classes. (No transparencies accepted.)

AWARDS AND OTHER INFORMATION

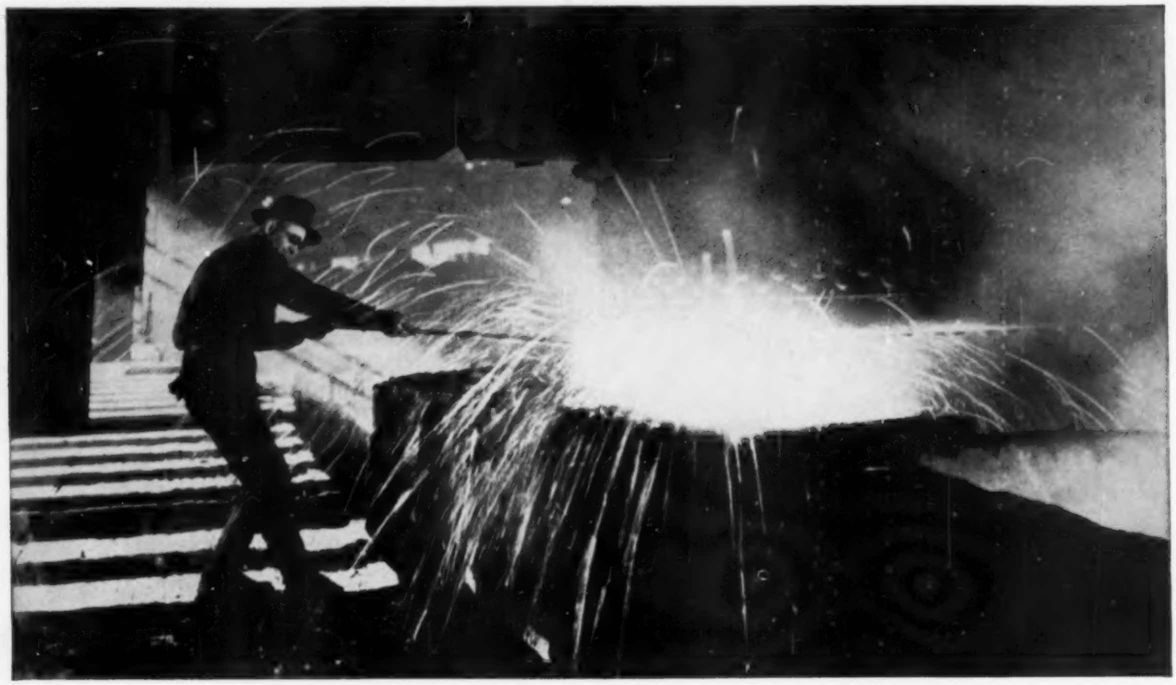
A committee of judges will be appointed by the Metal Congress management which will award a First Prize (a medal and blue ribbon) to the best in each classification. Honorable Mentions will also be awarded (with appropriate medals) to other photographs which in the opinion of the judges closely approach the winner in excellence. A Grand Prize, in the form of an engrossed certificate and a money award of $500 from the Adolph I. Buehler Endowment will also be awarded the exhibitor whose work is judged best in the show, and his exhibit shall become the property of the American Society for Metals for preservation and display in the Society's national headquarters.

All prize-winning photographs will be retained by the Society for one year and placed in a traveling exhibit to the various ASM Chapters.

41st NATIONAL METAL CONGRESS & EXPOSITION

INTERNATIONAL AUDITORIUM — — — CHICAGO — — — NOV. 1 to 6, 1959

THE U.S. TREASURY SALUTES THE PEOPLE IN THE STEEL INDUSTRY



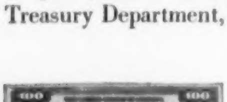
—who buy Savings Bonds and strengthen America's Peace Power

Men and women who earn their living in the steel industry can take great pride in knowing that their crafts and skills contribute, through raw material supplies, to nearly every other great industry in the United States. They can also be proud of the help thousands upon thousands of them are giving to America's Peace Power through the purchase of U.S. Savings Bonds.

Through regular purchase of Shares in America, these thrift-conscious people are reinforcing their own security after retirement, and establishing current reserves for such worthwhile family projects as new homes, education and travel.

If your company has not put in a Payroll Savings Plan thus far, you can start immediately. Just telephone your State Savings Bonds Director and accept the help he wants to give you. Or write to Savings Bonds Division, U.S. Treasury Department, Washington, D.C.

J. K. Thomson is shown here at his work in one of the great steel mills of this country. Like thousands of his fellow craftsmen, Mr. Thomson is making regular use of his company Payroll Savings Plan to contribute to the Peace Power of his country.



METAL PROGRESS

THE U. S. GOVERNMENT DOES NOT PAY FOR THIS ADVERTISEMENT. THE TREASURY DEPARTMENT THANKS, FOR THEIR PATRIOTISM, THE ADVERTISING COUNCIL AND THE DONOR ABOVE.

Metal Progress

Volume 75

January 1959 through June 1959

Metal Progress Is Owned and Published by
THE AMERICAN SOCIETY FOR METALS
7301 Euclid Ave., Cleveland 3, Ohio

Subject Index

The subject headings used in this index are chosen in accordance with the ASM-SLA Metallurgical Literature Classification, International (Revised) Edition, published by the American Society for Metals, 1958.

***(aa)* Atomic Age; *(br)* Book Review; *(c)* Correspondence; *(cp)* Critical Points; *(d)* Digest; *(ds)* Data Sheet; *(sr)* Short Runs**

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Author Index

ARMOROX

THERMOCOUPLES FOR DIFFICULT MEASUREMENTS SUCH AS

traveling tunnel kilns

special test equipment

oil refinery heater tubes

metal surfaces (magnetic)

diesel engine applications

in-motion measurements

and others

Bristol's Armorox thermocouple is good for temperatures up to 2000°F and at pressures to 50,000 psi.

Metal-sheathed, tightly packed with refractory insulation, Armorox is flexible. It bends easily around twice its own diameter to get into out of the way places.

Bulletin P1281 gives full facts on Armorox. Complete line of Bristol Thermocouples is described in Bulletin P1238. Write: The Bristol Company, 155 Bristol Road, Waterbury 20, Conn.
8.45

Thermocouple Wires
Iron-constantan
Copper-constantan*
Chromel-Alumel

Standard Sheath Materials
304 Stainless • Inconel†

Thermocouple Heads
Standard small head
Plug and jack head with screw lock
Permanent head

Standard Diameters (OD)
1/16", 1/8", 3/16", 1/4"

*T.M. Reg. by Hoskins Mfg. Co.
†T.M. Reg. by International Nickel Co.

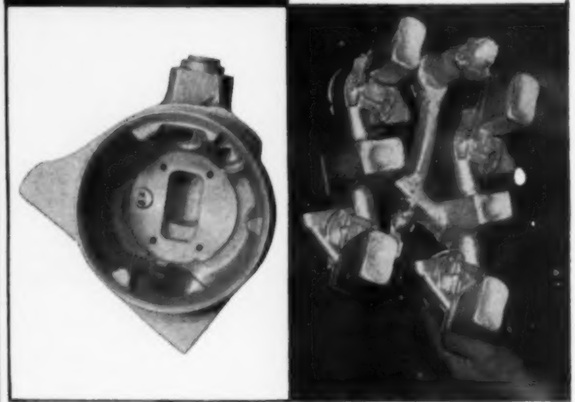
BRISTOL TRAIL-BLAZERS IN PROCESS AUTOMATION

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

FRONTIER 40-E

The Original High Tensile Alloy Made from Virgin Metals

Produces Aluminum Castings that can be Welded and Brazed



Scott Aviation Corp. Air-Pak castings made of Frontier 40-E Aluminum Alloy

DESIGN WITH LOWER WEIGHT AND GREATER RELIABILITY

FRONTIER 40-E is a primary alloy ingot made from virgin metals. A primary ingot gives you castings that are always the same — always reliable. Test bar physiqal properties are the same in the casting whether sections are thick or thin. FRONTIER 40-E is the original and proven, high strength, natural aging alloy — often imitated but never equalled. A natural aging alloy is the only kind that can be welded. FRONTIER 40-E is, therefore, ideal for composite structures where extrusions and cast parts must be welded together. Castings of 40-E can also be brazed providing a strong, uniform union.

Specify FRONTIER 40-E aluminum alloy castings and get the additional features of high shock resistance, high corrosion resistance and high tensile and yield strength. Send for complete information and name of nearest licensee.

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Exclusive Foreign Producers of 40-E
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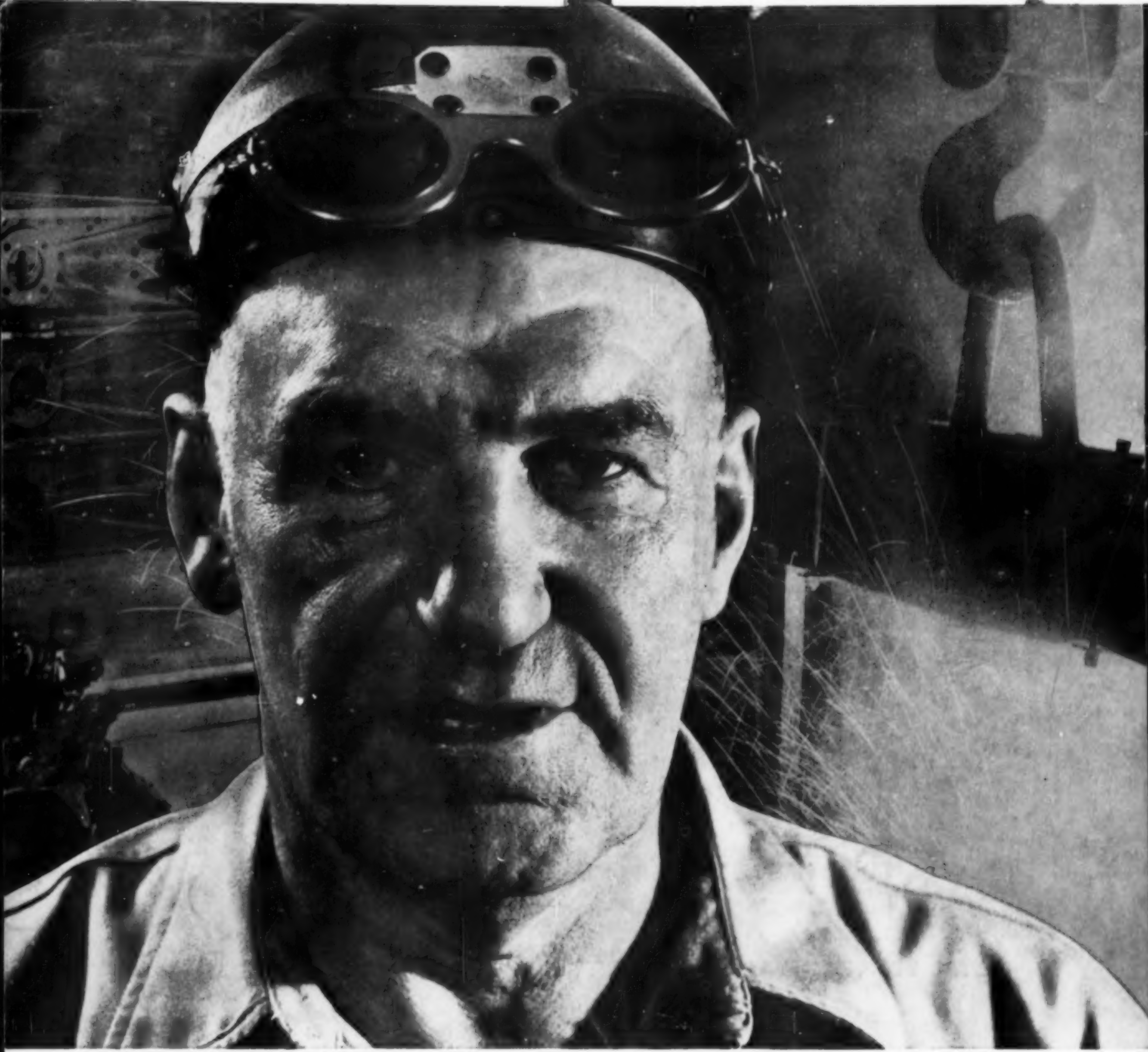
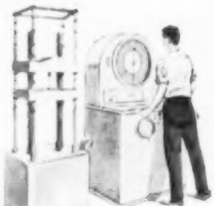


"I always get good ductility using calcium alloys"

Steel foundries employing aluminum deoxidation obtain improved properties by making a supplementary addition of calcium-silicon or calcium-manganese-silicon to the ladle. These calcium alloys help obtain consistently good ductility in the tensile test. Many foundries also report improved fluidity with the calcium additions. Generally 3 to 5 lbs. of alloy per ton insure effective treatment.

UNION CARBIDE METALS COMPANY, Division of Union Carbide Corporation, 30 East 42nd St., New York 17, N. Y.

Contact your UNION CARBIDE METALS representative for further information on getting improved ductility with calcium alloys.



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